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Microprocessor-based in-process infrared densitometer

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MICROPROCESSOR-BASED IN-PROCESS INFRARED DENSITOMETER

by

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MASTER'S THESIS

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Submitted to the Photographic Science and Instrumentation Division in partial fulfillment of the requirements for the Master of Science degree at the Rochester Institute of Technology

ABSTRACT

By the use of high performance solid-state infrared emitting diodes, matched infrared detectors, and a single chip 8-bit microprocessor, an in-process infrared densitometer has been designed and constructed. The device is capable of recording the build-up of optical transmission density on an exposed film sample as it develops, with no effect on the normal development process. The most novel feature of this system is a special development chamber with eleven built-in infrared densitometers. These densitometers are located as to read every other step of a standard Kodak #2 step-tablet exposure, and to allow the passage of developer across the film sample.

As an example, every other step of a 21-step exposure can be measured to produce a series of eleven density

readings in approximately 22 milliseconds. These measurements can be repeated from once every second to once per minute at any time during the development process. The microprocessor that controls the infrared densitometer has memory capacity to store the data required to generate 187 complete D-Log exposure curves. At the completion of processing, the density readings recorded earlier are available for user viewing on a large seven segment digital display system, or can be reproduced on a line printer.

D-Log exposure curves obtained from the device are in good agreement with curves obtained by conventional means. The device has a useful range of 0 to 3.00 density units with an accuracy of +/- .02 density units.

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INTRODUCTION

The design and construction of a device that would allow for the procurement of densiometric data from a sample of photographic film as it developed has been the subject of numerous thesis projects at the Rochester Institute of Technology. Some of these devices have been constructed, and feasibility proven, but their usefulness was extremely limited due to their primitive nature. The purpose of this thesis is to tie all previous efforts together in the design, construction, and testing of a completly new, workable, and reliable in-process IR densitometer.

The conceptual requirements for IR densitometery have been well known for years, but prior workers have either lacked the technology, or the expertise to construct a truly significant device. This project makes use of state-of-the-art technology along with industry standard development and assembly techniques in its design and construction. Therefore, the general aim of this project is to produce a research instrument of the highest possible caliber to allow those qualifed to study photographic processing.

Of the many possible uses for this device, induction period studies have received foremost consideration in its design. The ability to monitor changes in the rate of development and to know exactly when the developer makes actual contact with the emulsion are absolute necessities when attempting to determine the length of the induction period. This is where the conventional method of arresting development fails. The procedure becomes inaccurate at short development times. The IR densitometer, however, has been designed to monitor density build up on a second-by-second basis, thus providing an accurate record of exactly how the film sample developed.

Prior Work:

Conceptually, the design of an in-process IR densitometer is quite simple. All that is really needed is:

1.) A source of infrared radiation to which the film being investigated is insensitive.
2.) Some method of directing this radiation through the developing film sample.
3.) The collection and detection of the radiation after it has passed through the sample.
4.) A method of relating the detected signal to some type of optical transmission density.
5.) An output system which will deliver the desired sensitometric data to the operator in some convenient form.

However simple this may sound, it has taken almost fifteen years and the contributions of many individuals to reach the point where all prior efforts could be concentrated into the construction of a truly significant and useful in-process IR densitometer.

One of the earliest uses of infrared densitometry was made in 1953 by Fortmiller and James[1]. They used a device that would be the predecessor for future designs at the Rochester Institute of Techonolgy. Their apparatus was used to study the kinetics of development of a fine grain motion picture positive emulsion by vanadous ion.

The first attempt to actually build such a device at R.I.T was made by Hughes in 1964[2]. As it was only a B.S. thesis, the project was somewhat limited in scope, but the conceptual feasibility of in-process IR densitometery was shown.

Hughes IR source consisted of a tungsten display case lamp filtered with a Wratten No. 70 filter. The radiation was directed onto a developing sensitometric exposure fastened to the bottom of a plastic tray. From the other side of the tray, 84 plastic rods piped the IR radiation to a large collar with a single L-shaped light pipe mounted in the center. This L-shaped rod then had a silicon photovoltaic cell located on axis so as the rod was rotated, it could scan all 84 pipes and direct their output onto the single photocell. The pipes were scanned by the rotating rod at such a rate as to produce 40 characteristic curves per second. The output of this cell was then logarithmically amplified and displayed on an oscilloscope screen. The screen was photographed by a single frame motion picture camera and the resulting images could be projected onto an empirically determined transfer curve relating wet IR density to dry white light density.

The problems encountered in this system were numerous, the major ones being non-uniformity in transmission between the light pipes and poor photocell sensitivity at high densities. However, the five neccessary sub-systems called for in the earlier paragraph concerning conceptual simplicity were present.

1.) IR source: tungsten lamp and Wratten filter.
2.) Radiation through-put: plastic light pipes.
3.) Detection: rotating silicon photocell.
4.) Relation of system output to density: log amp and transfer curve.
5.) Display: oscilloscope, movie camera, and projector combination.

In 1970, a second endeavor was made to construct an IR densitometer by Hisler and Casinelli[3]. The five major sub-systems of their design can be outlined as follows:

1.) IR source: one six-volt, fifty watt tungsten lamp filtered by three Kodak No. 29 Wratten filters.
2.) Radiation through-put: single emitter/detector combination. Developing sensi-strip was mechanically moved through IR beam by being mounted inside a revolving plastic cylindrical tank. Method of rotation was a phonographic turntable which would produce one complete scan of the sensi-strip every .77 second.
3.) Detection: single photomultipler tube from a Macbeth TD-102 densitometer with an S-4 response.
4.) Relation of system output to density: output of TD-102 fed directly to oscilloscope, logging and scaling performed by TD-102 electronics.
5.) Display: oscilloscope screen with copies being made by a Polaroid scope camera. Type 107 film was used.

The major problem with this system was the mis-match in peak spectral responses of the source/detector combination. Add to this the necessity of three Wratten No. 29 filters to prevent film fogging and it is understandable why no useable output was obtained.

A third series of design improvments were proposed and implemented in 1971 by Beaupre and Jasper[4]. Their system consisted of:

1.) IR source: a single 120-volt, 500 watt Sylvania EHA tungsten-halogen projector lamp filtered by Kodak Wratten filters Nos. 87 and 87C.
2.) Radiation through-put: same rotating turntable arrangement used by Hisler and Casinelli.
3.) Detection: Hewlett-Packard PIN photodiode.
4.) Density transformation was performed by a solid state logarithmic amplifier.
5.) Display was same as that used by Hisler and Casinelli.

that is, an oscilloscope and Polaroid scope camera.

This device was tested with Eastman Kodak Fine Grain Release Positive Film, type 5302, developed in DK-50 and D-76. The results of their experiment demonstrated good agreement between conventionally obtained characterstic curves and their IR obtained ones. However, beyond a density of 2.5, curve deviation due to non-linearities in their amplifier became significant, thereby limiting the useful range of the device.

The first attempt to use the above device as an actual research tool, and not a single project in itself, was made by Turbide and Williams in 1972[5]. They investigated the phenomenon of lith or infectious development. Film type used was again 5302 and ortho Kodalith type 3, 2556. No modifications were effected upon the device and the only significant contribution of this endeavor was to simply repeat those results obtained by Beaupre and Jasper.

In an attempt to increase the useful density range of the instrument, Turbide and Williams tried removing the anti-halation backing of their sensi-strips before development. But even with this, the device gave linear results only out to a density of about 2.4.

A more comprehensive write-up and representative curves are contained in an article written by B.H. Carroll[6] summarizing the work of Jasper, Turbide, and Williams. Technically, the paper deals little with the construction and operation of the densitometer, but rather with the subject for which the project was performed; photographic chemistry.

Industry references to IR densitometery are scarce, but two major ones will be mentioned here in the hopes of demonstrating that the concept is not merely an academic curiosity. In 1966, Spitzak[7] made use of solid state IR emitters and silicon photodetectors in a film scanning system. The ultimate purpose of the system was to scan photographs of planets obtained by spacecraft, digitize the signal, and transmit them to earth. As a side note, the author mentions the possibility of using such a system to perform density measurements before fixing the film to determine the degree of development.

More in keeping with the scope of this project, Keemink and Van der Wildt[8] designed and built a device which they called a gammascope. The main intention of this project was to monitor the density build-up of a piece of film while it was developing, and then to arrest the process when a certain value of gamma was reached.

The conceptual layout of this system is very similar to that under consideration in this paper. An array of discrete IREDs (infrared emitting diodes) with matching discrete photocells situated such that twelve positions of a continuous density wedge (maximum density of 2.00), could be scanned during development. The output of the photocells is then electronically transformed into density values by a logarithmic amplifier. From here, the materials characterstic curve is displayed upon an oscilloscope screen as a series of discrete "dots". Gamma could then be determined by fitting a line through the linear portion of the curve and calculating its slope.

It is within this body of work where the first mention of problems involving the Herschel effect is encountered. Decreases in density were stated to occur when repeated scans were made in the earliest states of development. It is at this point when latent image centers are not yet rendered fully developable and are most susceptible to deterioration by IR radiation. This condition can be further aggravated by the use of very dilute developer solutions. The authors suggest that this problem can be avoided by performing no scans during the first minutes of development. However, one of the most important design aspects of an in-process IR densitometer is to gather sensiometric data during precisely the first moments of development in order to study induction effects.

The most recent work in the field of IR densitometery was performed in 1976 by Piskacek[9]. His M.S. thesis was a natural progression of previous work leading up to a final proof of in-process IR densitometry feasibility.

The body of his project dealt with the design of a special chamber which would allow a sensiometrically exposed piece of 35mm film to be scanned by IR radiation while it developed. His specifications called for an array of eleven solid state IR emitter/detector combinations to be mounted within the chamber to facilitate density measurments being taken from a 21-step sensitometric exposure.

Not only was the chamber designed, but the materials called out by his plans were tested for their suitability in a developer environment (e.g. extreme excursions in pH). Also, any material which was to be used in the transmission of IR was tested for its optical properties and possible attenuation in the IR.

Although Piskacek was unable to actually build his chamber, he was able to bench test a small portion of the electro-optical system. Using an IR emitting diode, (Monsanto ME5) and a solid state detector, (UDT-500, effective area .05 cm^2), he was able to obtain a linear correlation between unfixed IR density and fixed out white light density. Agreement was good out to a maximum density of 2.00.

General Design Considerations:

Piskacek's work in 1976 was one of the last design steps necessary for the construction of a truly significant and useful in-process IR densitometer. Very little was said, however, about the design of a working densitometer from a systems approach. Piskacek used a simple block diagram point of view for detailing how he thought the remainder of the densitometer should be configured. In all actuality, he really intended for the remaining work to be carried out by someone else, and purposely left any electronic designs vague.

Picking up where Piskacek left off, a complete IR densitometer system can be generalized. His selection of IR emitters and detectors mounted in a specially designed development chamber would produce eleven discrete optical transmission signals. Some of the most important design considerations for this system are that these signals be generated quickly (on the order of milliseconds), accurately (within +/- .02 density units), and over a density range of 0 to 3.00. Another important consideration is an efficient and convenient method of storage and display of density data. The old method of photographing an oscilloscope screen would not be suitable for the system being considered here.

To meet the above generalized requirements, a single chip 8-bit microprocessor has been selected as the system controller. Microprocessors are ideally suited for the rapid control, storage, and display of data. For this particular system, the microprocessor will control the sequential pulsing of the eleven emitter/detector pairs to generate eleven optical transmission signals. By the use of an analog multiplexer, it will direct these signals to a high-performance logarithmic amplifier, and then put them into digital form for input to the microprocessor. The output system will consist of a light emitting diode display of the actual density values, or permament records of density information can be generated on a line printer.

The overall design philosophy is to construct a device that can be used as a research instrument by scientific personnel.

IR Densitometer System Description:

The design of the in-process IR densitometer can be broken up into three major functional groups. These three groups are: data acquisition, data management, and data output. Although all groups are under total control of the microprocessor, this functional grouping will aid in understanding the system as a whole (see figure 1).

Data Acquisition:

The major component of this sub-system is the development chamber. The chamber is a precisely machined block of stainless steel designed to hold a strip of 35mm film in registration against eleven solid state IR densitometers while developer is pumped across the sample. The chamber is made up of two matched sides that mate to form the development cavity. It is connected at the bottom by a hinge pin (see figure 2) and sealed at the top by a locking pin. The top section contains the eleven IR emitting diodes (General Electric LED55C, see appendix 4 for complete specifications). Each diode is mounted in a small tube with a lens at the end (f=5mm). This assembly is mounted in a guide hole behind a plastic window and focused onto its companion detector below. The bottom section contains the eleven IR detectors. They too are mounted behind a plastic window and when the chamber is sealed, are in perfect registration with the emitters on top and create eleven discrete, solid state mini IR densitometers. The detectors (UDT-450's, a photodiode-operational amplifier combination, see appendix 5) produce an optical transmission signal directly. These eleven outputs are fed into an analog 16-channel multiplexer. A multiplexer is simply a 16-position switch with one common output. The switch selected, however, depends on the state of four address lines into the multiplexer. In this way, the output of an individual detector

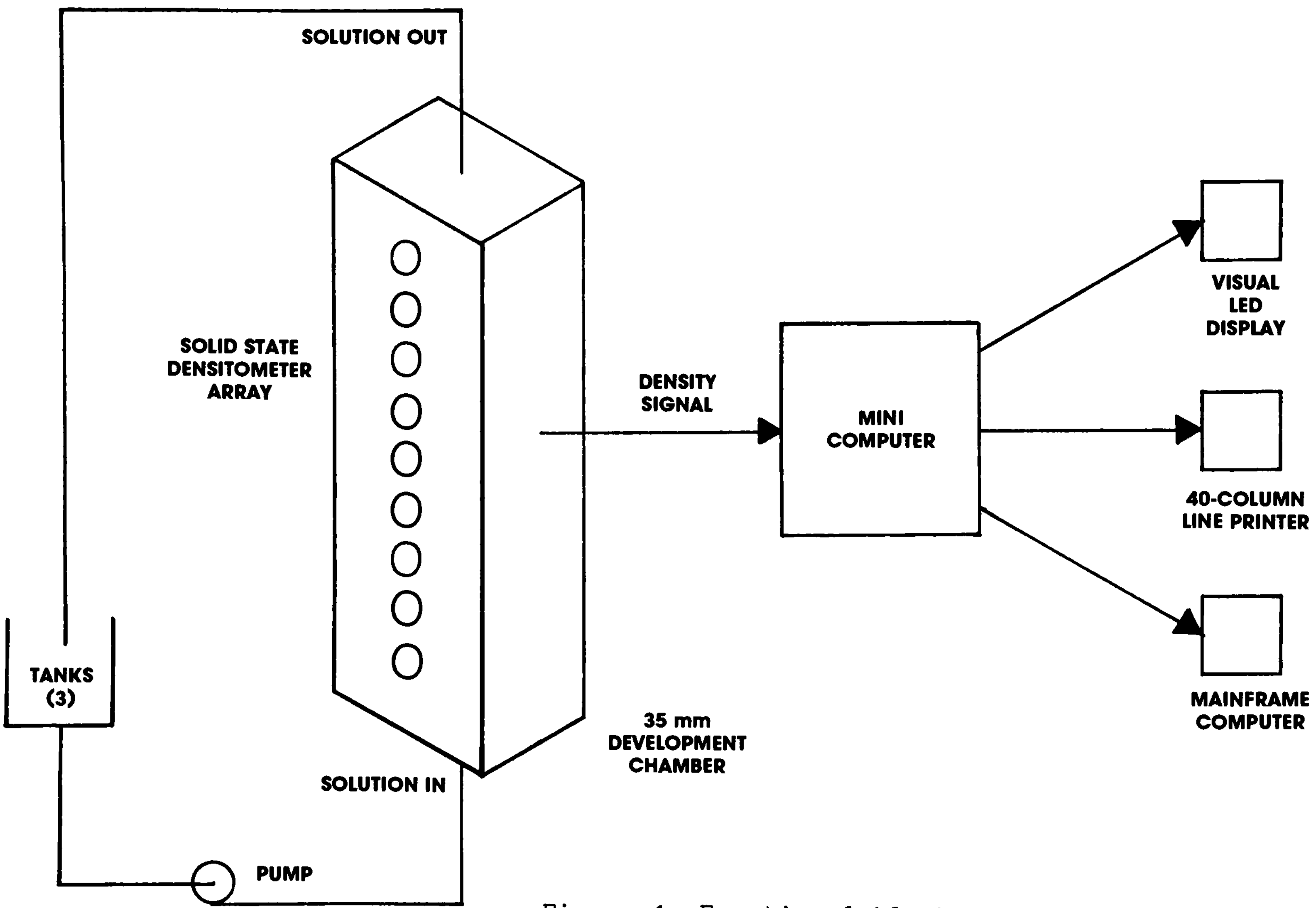

Figure 1: Functional block diagram

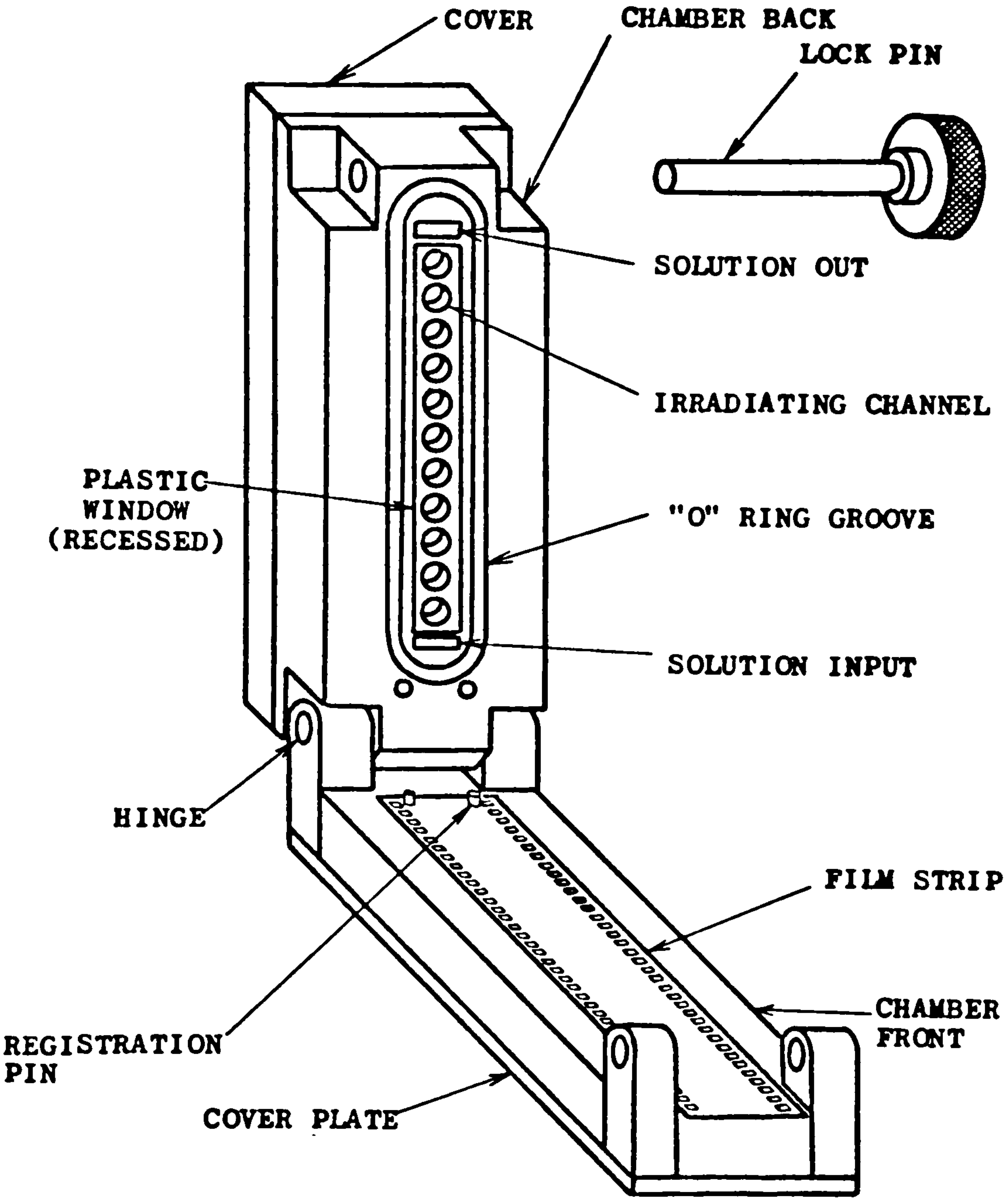

Figure 2: Oblique sketch of the development chamber

can be selected and processed within the array of eleven. Due to this one-at-a-time selection of the detectors, the term "array scan" becomes useful in describing how the eleven emitter/detector pairs are sequentally pulsed to make a complete reading of the optical transmission density (commonly called "density") of the developing film strip. To take a density measurment of the film sample, the first emitter/detector pair is switched on, a reading made, switched off, the second pair turned on, etc. Hereafter, a complete set of density measurments for a film sample will be called a "scan". A scan produces eleven density readings and takes approximately twenty-two milliseconds to perform. Keep in mind that all scan timing and signal processing is performed under the direction of the microprocessor.

From the multiplexer, the analog transmission signal is fed into a logarithmic amplifier (see appendix 6). Here the log of the input voltage is taken to produce an analog transmission density signal. This log amplifier has been scaled to produce a two volt change in output for a ten times change on the input. In other words, a sample density of 1.00 produces an output voltage of 2.00 volts, a density of 2.00 gives an ouput of 4.00 volts, etc. This signal becomes the input to a 10-bit analog to digital converter. The output of this device is a 10-bit digital density signal, which is in a form ready for input to the microprocessor.

These components make up the data acquisition group. Note that any component that operates on analog signals is considered part of the data acquisition system. Once the signal becomes a 10-bit digital word, it enters the digital domain and remains there until final output.

Data Management:

The data management sub-system is made up entirely by the Intel SDK-85 single board computer (see appendix 7). This board contains the Central Processing Unit (CPU) or what is better known as the microprocessor. It also contains all memory elements, input/output devices, time bases, and display controllers. A complete description of how this computer works is contained in the SDK-85 System Design Kit User's Manual #9800451B.

The reason the IR densitometer was designed to be controlled by a computer is twofold. Of the many problems encountered in earlier IR densitometer designs, accurate timing of the density scans and a convenient means of data storage and display were two of the most difficult to solve. These are areas, however, where microprocessors excel. They operate on a very accurate crystal time base, and are able to store large amounts of data very quickly.

Once the 10-bit digital density word leaves the A/D converter, it is brought into the SDK-85 bus structure through two 8-bit I/O ports (see figure 3). The system bus is the means by which data is transported within the computer itself. This data is then immediately stored in random access memory (RAM) for later processing. As each scan produces a burst of eleven density readings, this data is stored as eleven 10-bit word blocks. From RAM the data is processed further (i.e. scaled in accordance with certain calibration procedures) and becomes ready for output.

Data Output:

For computer data to be of any use, there must be some convenient method to present this data to the user in the real world. For the IR densitometer, the user has three methods of

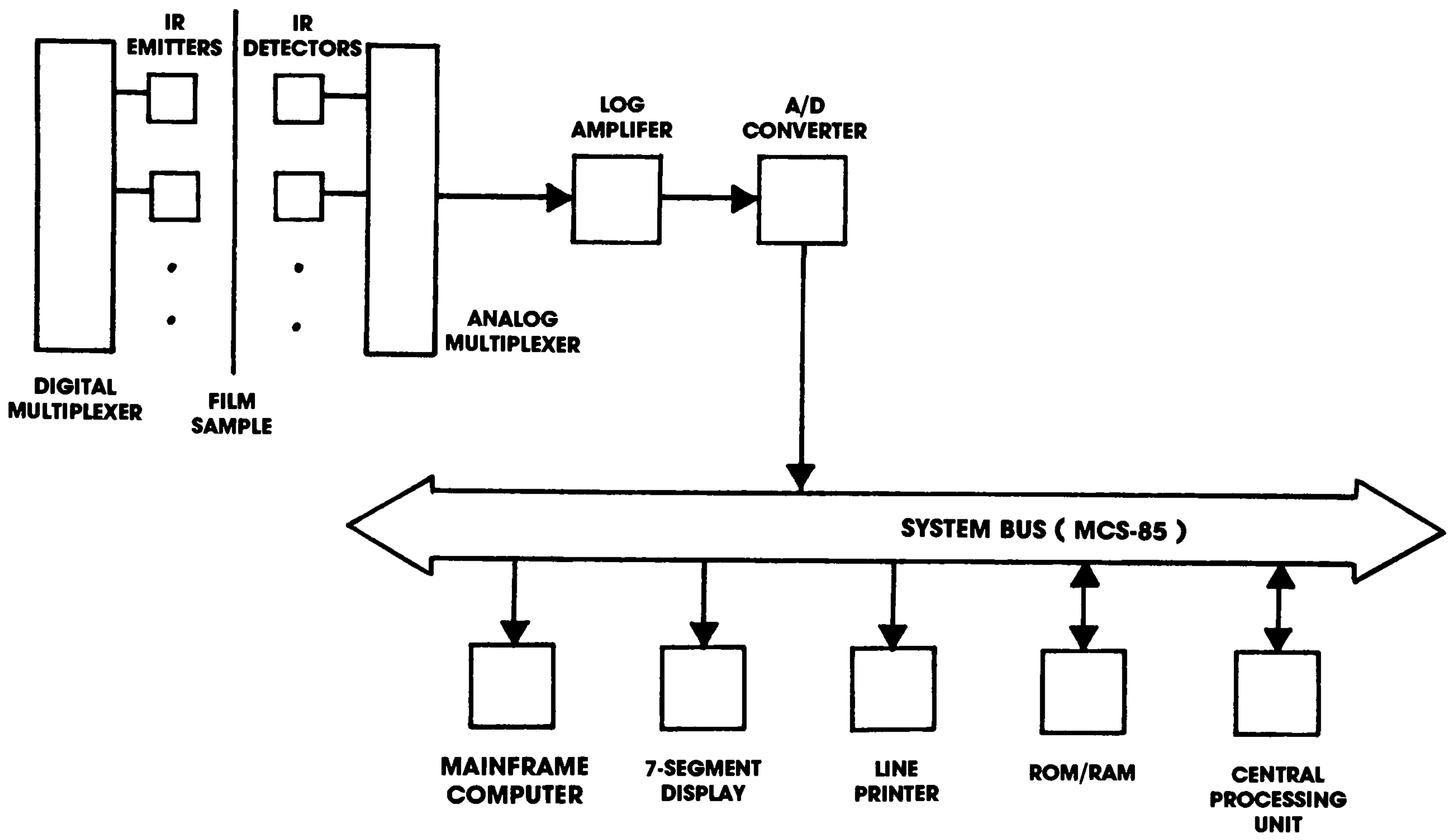

Figure 3: System block diagram

data output. The first output system is for the immediate viewing of density data. The computer can be directed to display any density scan on a 33-digit light emitting diode (LED) display. The system will display all eleven density readings from a single scan. The format for a single reading is X.YZ. That is, each reading is accurate to three significant figures, i.e., with a resolution of +/- .01 optical density units.

The second method of data output is through a 40-column line printer. Any set of density readings on the LED display can be reproduced on the line printer. This is to allow the user to generate a permanent record of any particular density scan. For a complete description of these two output modes, please consult the In-Process IR Densitometer User's Manual*.

A third method of data output has been partially provided. Connectors have been installed to allow for the connection of this computer to a higher level computer. With this type of inter-connection, data could be transferred to the higher level system for even more processing of density data. As an example, computer graphics could be used to create D-Log E curves on a CRT screen. Completion of this interface depends on what type of higher level computer is selected, and therefore has been left as a separate project.

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* The IR densitometer user's manual begins on page 63.

Data Acquisition System Analysis:

Information within the IR densitometer can be either in analog form or digital form. An analog signal is a voltage that can vary infinitely over a given range. A digital signal is a voltage level that can vary only in discrete steps. This particular digital system is binary; the voltage signal has only two levels, low and high ("0" and "1"). When working with digital systems, very strict and well known rules of logic apply. For analog systems, however, events are not so well defined. It is the intent of this section to provide a set of equations that will describe the operation of the analog system within the IR densitometer.

Figure 4 shows the physical relationship of the components that make up a single densitometer. Figure 5 gives a schematic representation of the same densitometer, along with the other components that make up the analog system. The figure presents an ideal system configuration where all devices are considered to be perfect and introduce no errors.

The IR emitting section consists of the IRED, lens tube, and lens which is used to focus the output of the IRED onto the detector surface. The power per unit area incident on this surface is the irradiance and is expressed as H watt/cm^2. The detector surface has an active area of A cm^2 and a responsivity of R amp/watt. The peak output of the IRED and peak responsivity of the detector are so well matched that no wavelength term need be included in the calculations that follow.

With these terms now defined, the current generated by the photo-diode is given by:

$$I_T = (T)(H \text{ watt/cm}^2)(A \text{ cm}^2)(R \text{ amp/watt})$$

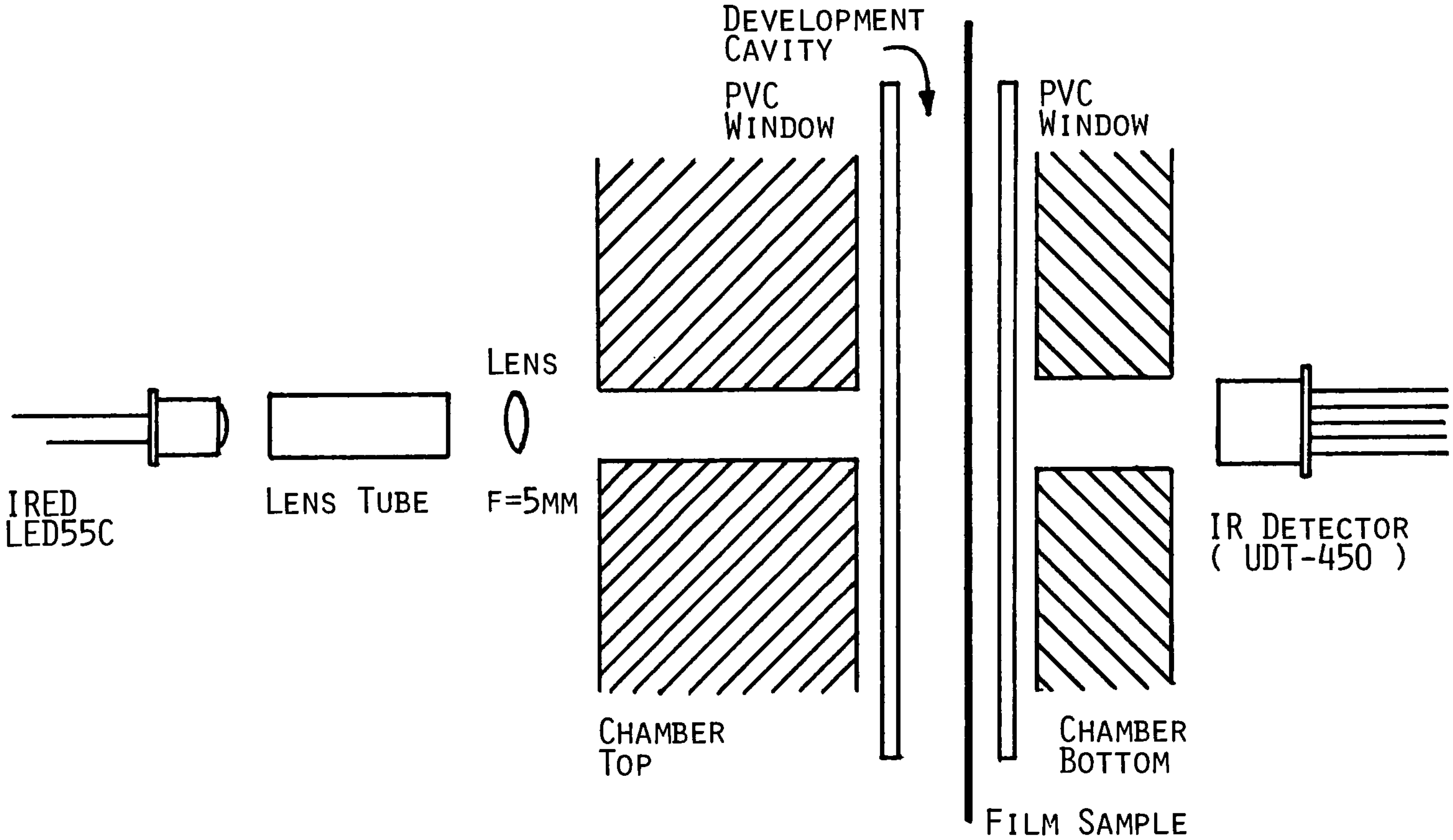

FIGURE 4: EXPLODED VIEW OF A SINGLE DENSITOMETER

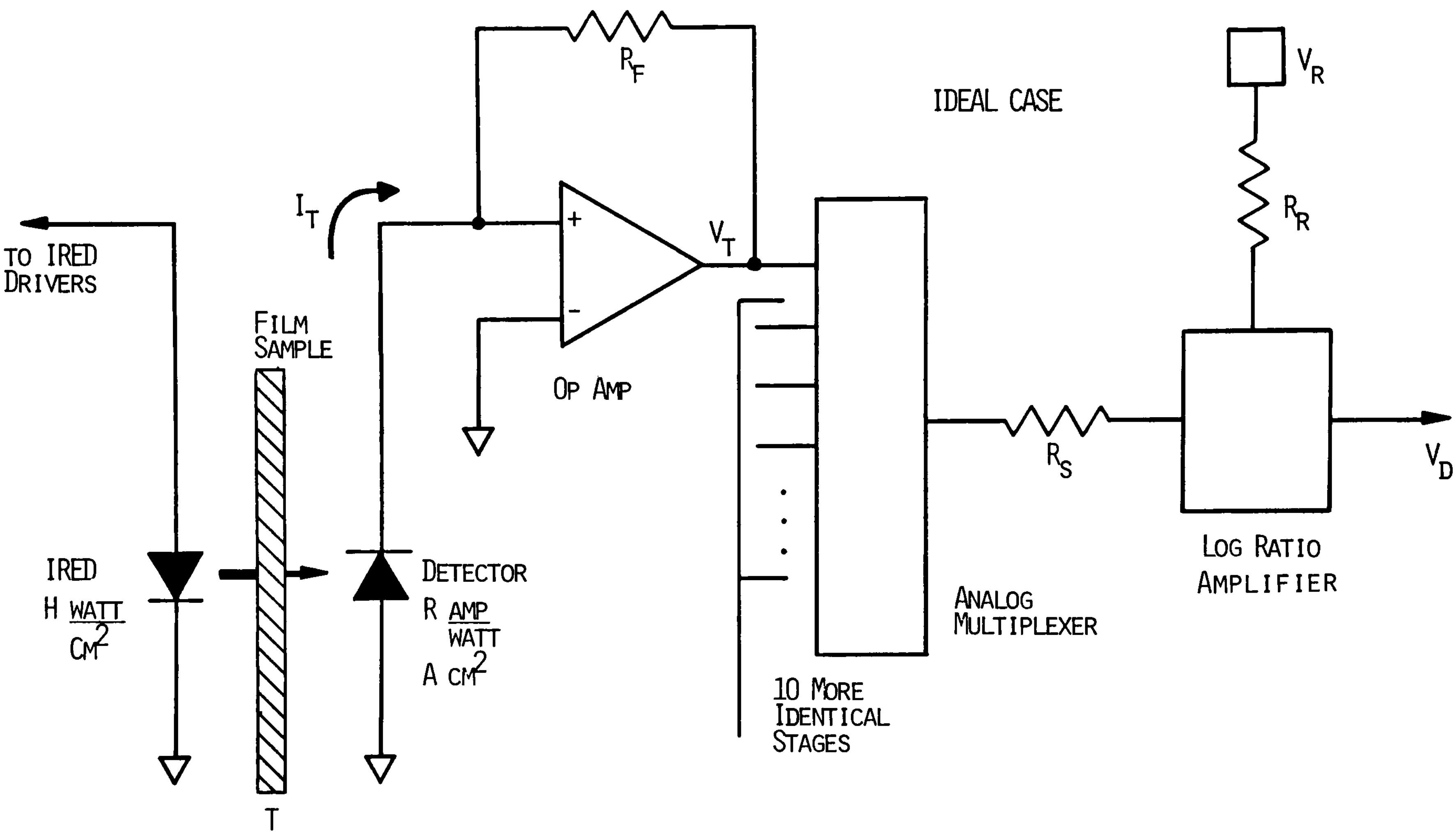

FIGURE 5: IDEAL ANALOG SYSTEM CONFIGURATION

The output voltage of the operational amplifer is:

$$V_T = R_F \cdot I_T$$

where R_F is the feedback resistance in ohms.

Now the sample transmission T, can also be expressed as a density:

$$T = 10^{-D}$$

Substituting:

$$V_T = H \cdot R \cdot A \cdot R_F \cdot 10^{-D}$$

The irradiance, responsivity, active area, and feedback resistor all remain constants, and can be collected into the term C.

$$V_T = C \cdot 10^{-D}$$

Neglecting any effects from the analog multiplexer, this V_T is input to the logarithmic amplifier. The transfer equation for the log amplifier is:

$$V_D = -K \cdot \mathrm{Log}(I_S/I_R)$$

where I_S is the signal current and I_R is a reference current. To place the expression in voltage terms:

$$I_S = V_T/R_S \quad \text{and} \quad I_R = V_R/R_R$$

Substituting:

$$V_D = -K \cdot \mathrm{Log}(V_T/V_R \cdot R_R/R_S)$$

V_T is known and can be substituted:

$$V_D = -K \cdot Log(C \cdot 10^{-D}/V_R \cdot R_R/R_S)$$

V_R is a precision reference, and therefore a constant. R_R and R_S are resistors; also constants and can be removed.

Let:

$$M = C \cdot R_R \; / \; V_R \cdot R_S$$

And:

$$V_D = -K \cdot Log(M \cdot 10^{-D})$$

$$V_D = K \cdot D - K \cdot Log(M)$$

Notice that $-K \cdot Log(M)$ is just another constant, therefore combine it form N.

Lastly:

$$V_D = K \cdot D - N$$

This analysis shows that the output voltage of the log amplifier is simply a scaled version of the film sample density, plus some additive constant, N. For this particular system, K was made to equal 2.0. The constant N presents no problem as it can be nulled nearly to zero by an external offset adjust on the Log amp. Any remaining offset error can then be removed by software calibration routines. Therefore:

$$V_D = 2 \cdot D - N$$

The log amplifier is the last element in the analog system. From here, V_D is converted to a 10-bit digital word and then enters the digital system.

In reality, all the components of the analog system are non-ideal and each has a certain amount of error associated with it. The most critial types of errors are voltage offsets and non-linearities. Within the entire system, only two devices have these problems to any appreciable degree. They are the operational amplifiers and the logarithmic amplifier. The remaining devices introduce errors so small as to be negligible, or they cannot be characterized. Figure 6 again shows the analog system configuration, but this time the two major sources of error are shown as offsets D_1 and D_2.

An ideal op-amp would have an output voltage of zero volts when the photo-diode connected to it was in complete darkness. This, however, is not the case. Due to temperature drift, noise pick-up and other effects, a trim pot has to be connected to each amplifier to zero out these offsets. No offset adjustment is perfect, and the remaining offset is called D_1.

The output of the op-amp now becomes:

$$V_T = R_F \cdot I_T + D_1$$

The operation of the logarithmic amplifier is also non-ideal and has two types of errors associated with it. The first is an offset D_2 which is present for similar reasons as in the op-amp. The other type of error is something called Log Conformity Error (LCE). LCE is the error expressed in the output's ability to perform an accurate logging function of the input. Hence the LCE is always expressed Relative To Input (RTI). For the Analog Devices log ratio amplifier:

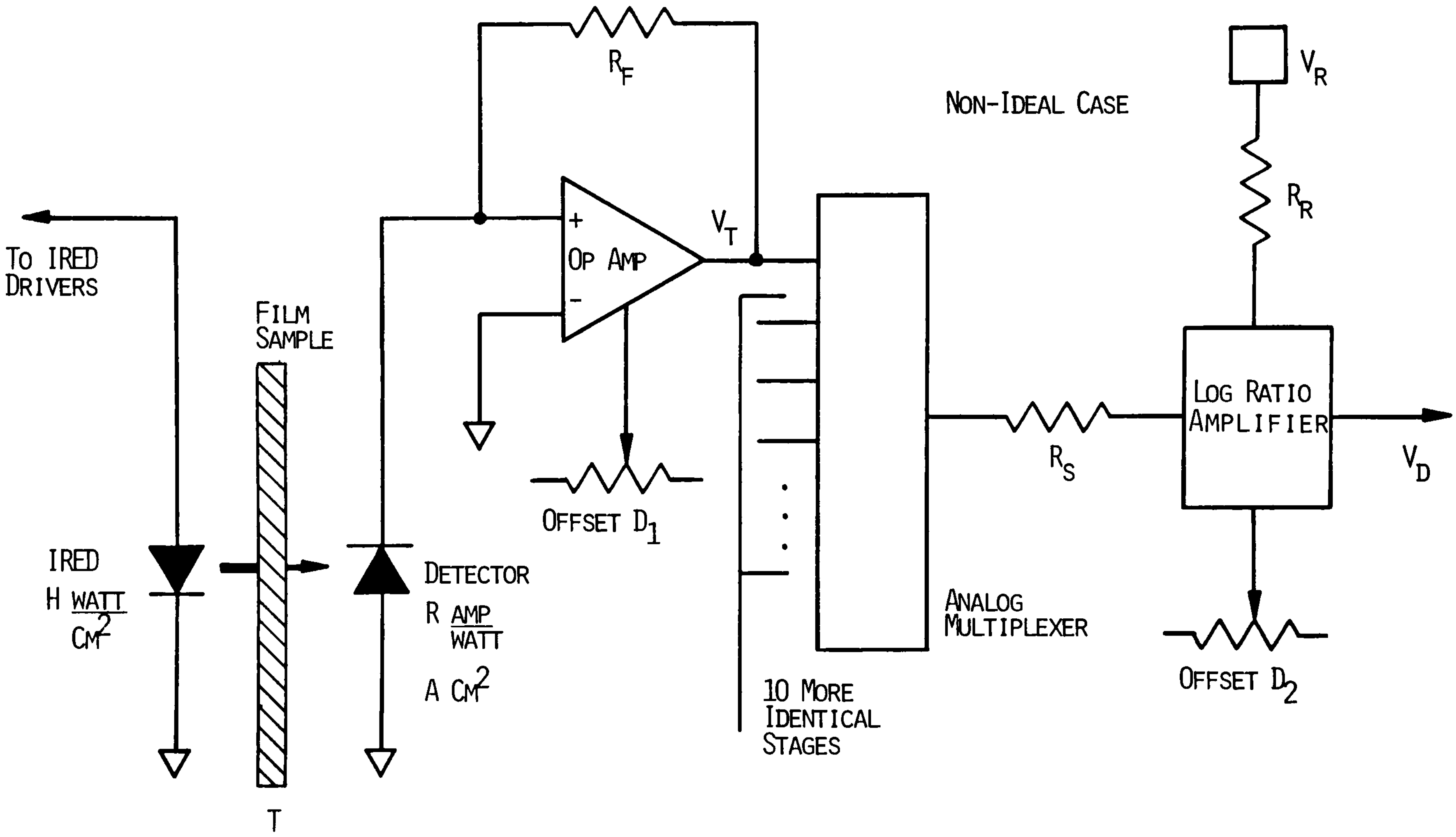

FIGURE 6 : NON-IDEAL ANALOG SYSTEM CONFIGURATION

$$LCE = +/- 1\% \ RTI$$

These errors manifest themselves in the transfer equation for the device as:

$$V_D = -K \cdot Log(1.01 \cdot (V_T/V_R \cdot R_R/R_S)) + D_2$$

Substituting in for V_T:

$$V_D = -K \cdot Log(1.01 \cdot ((C \cdot 10^{-D} + D_1)/V_R \cdot R_R/R_S)) + D_2$$

$$= -K \cdot Log(1.01 \cdot C \cdot R_R \cdot 10^{-D}/V_R \cdot R_S + 1.01 \cdot R_R \cdot D_1/V_R \cdot R_S) + D_2$$

$$= -K \cdot Log(C \cdot R_R \cdot 10^{-D}/V_R \cdot R_S \cdot (1.01 + 1.01 \cdot D_1/C \cdot 10^{-D})) + D_2$$

Since:

$$M = C \cdot R_R/V_R \cdot R_S$$

Then:

$$V_D = -K \cdot Log(M \cdot 10^{-D} \cdot (1.01 + 1.01 \cdot D_1/C \cdot 10^{-D})) + D_2$$

$$= -K \cdot Log(M \cdot 10^{-D}) - K \cdot Log(1.01 + 1.01 \cdot D_1/C \cdot 10^{-D}) + D_2$$

From ideal case :

$$V_D = -K \cdot Log(M \cdot 10^{-D})$$

$$= K \cdot D - N$$

Therefore, in the general case:

$$V_D = K \cdot D - K \cdot \mathrm{Log}(1.01 + 1.01 \cdot D_1/C \cdot 10^{-D}) + D_2 - N$$

Ideal Term — Error Term

The output voltage of the log amplifier can now be expressed as the sum of an ideal term and an error term. Note that the error term is not a constant but rather a function of the film sample density. Note also that if the LCE were 1.00 (ideal) and the op-amp offset D_1 were zero, the error term would vanish and only D_2 would remain.

This error analysis details which sources of error are important and which ones are not. The offset errors D_2 and N are simple additive constants and can be easily subtracted out later by a computer software routine. The LCE and the offset D_1, however, are not insignificant. They produce a logarithmic error which is a function of density. It is extremly difficult to perform logarithmic functions with assembly level software, therefore, these errors cannot be removed by any calibration routine. What must be done is to minimize the effects of these errors. Log Conformity Error is fixed. It will always be present and cannot be removed. On the other hand, D_1 can be made to be very close to zero. Any error introduced by the offset D_1 becomes appreciable only at higher densities. For this particular system, D_1 can be kept to about + 3 millivolts. This along with the LCE translates into an error of about -.06 density units at a sample density of 3.00. This is indeed acceptable, and the error is almost non-existent at lower densities.

Figure 7 is a graphical representation of how detector offset errors affect density measurements. Input density is to be considered actual sample density, while output density is the

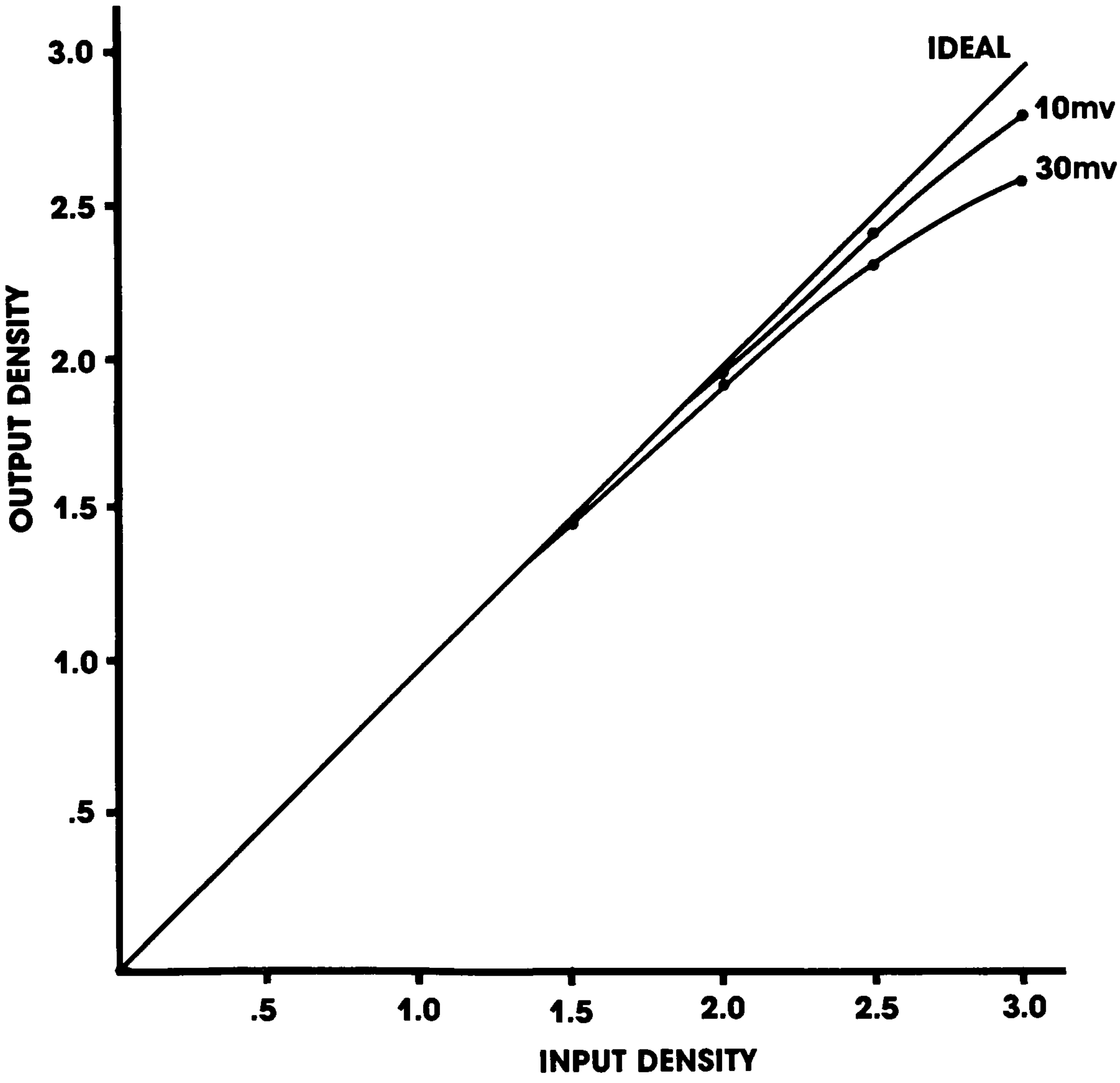

Figure 7 : Output density vs. input density for different levels of amplifier drift.

density reported by the system with the above transfer equation. The numbers used in that equation for the generation of figure 7 are based on actual constants used in the physical system. Only positive offset errors are shown in the figure as negative offsets have a completly different effect on the system. This is because the physical log amplifier produces undefined output voltages for negative inputs. What really tends to happen is the amplifier output will saturate (go to maximum output voltage, which is about 14.3 volts). If the analog to digital converter were able to resolve this voltage (10.00 volts is it's maximum), the computer would think a sample density of 7.0 were being read. Therefore, to prevent such events from happening, the offset null trim pots for the eleven detectors are purposely adjusted to produce a positive offset of a few millivolts at all times. This precludes the possibility that the detectors might drift and produce a negative output. This method, of course, introduces some slight error, but to have a density reading that is somewhat lower that reality, is considered far better that a reading of 3.0 being reported as 7.0.

Experimental Verification:

The purpose of this section is to demonstrate two of the most important operational capabilities of the IR densitometer. They are:

1.) The ability of the device to relate wet, un-fixed IR density to dry, fixed-out diffuse density in a linear fashion. Also that for the same development time, wet, un-fixed IR D-Log exposure curves are in good agreement with dry, fixed-out diffuse D-Log exposure curves.

2.) Repeatibility. Most data has been replicated three times to demonstrate the repeatability of the IR densitometer. This data has been tabulated for ease of viewing (see tables 1,2, and 3).

Three series of experiments have been run to obtain sufficient data for conclusions to be drawn about the above two statements. The two film types used were selected because of their relatively simple emulsions. It was also desired to run the experiments with a fairly active developer, and a much milder developer, hence D-19 and D-76 were selected. Details on how these experiments were run are listed below.

Series 1:

Eastman Kodak Fine Grain Release Positive, type 5302, was processed in D-19 at 70° F for 5 minutes. Sensitometery consisted of film samples being exposed in a Kodak model 101 sensitometer. A Kodak #5 step tablet was used along with a 1.20 Inconel N.D. filter. The sensitometer provided 340 lux·seconds at the wedge. Three runs were made with fresh developer and rinse water. To prevent contamination of the Fluid Transport System, no other chemistry was introduced into the system. Scans were taken once per second for the first minute, then once every 10 seconds for the remaining 4 minutes. No scans were taken during the one minute water rinse that followed development.

All processing was done under Kodak 1A safelight conditions. After the water wash, film samples were tray-fixed for five minutes then washed for twenty minutes and dried.

Results from the first run of this series are shown in figure 8. Wet, un-fixed IR density is plotted as a function of step # (actual Log exposure values can be found at the end of this section). Curves obtained after 30 seconds, 2 minutes and 5 minutes of processing are shown, with the 5 minute curve being the last one obtained before the water wash.

The curves show just about what one would expect for this type of developer/film combination. After about 2 minutes of development, there is no further increase in gamma. At about the same time, toe densities, as well as the over-all sample density, begin to pick-up dramatically. For this sample as with all the others, the IR densitometer would report an initial density of approximately .18 a few seconds after developer contact. This increase in density is due to the fact that the specular optical density of AgBr microcrystals embedded in gelatin is strongly dependent on the water content of the emulsion[10]. Also, the optical density does not depend directly on the thickness of the gelatin, but rather on its index of refraction. As water is absorbed by the emulsion, the index of refraction will increase, causing an increase in scattering and therefore, and overall increase in density will be observed.

Figure 11 shows unfixed, wet IR density plotted against fixed-out dry visual diffuse density. All dry density readings are made on a Macbeth TD-504 digital densitometer. Some of the data points are rather far apart because of the high contrast for

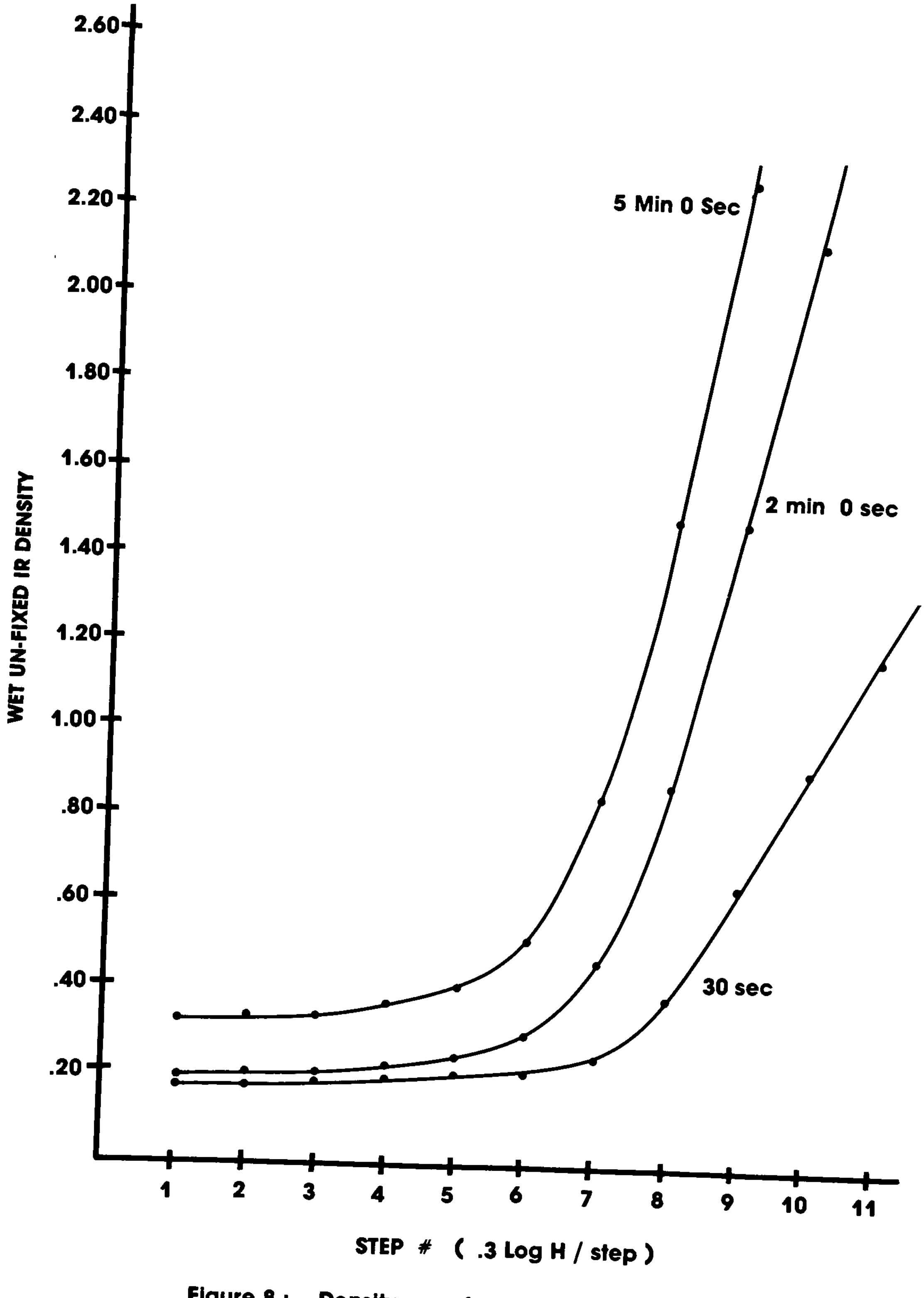

Figure 8 : Density as a function of Log exposure for Eastman Kodak Fine Grain Release Positive, type 5302, developed in D-19.

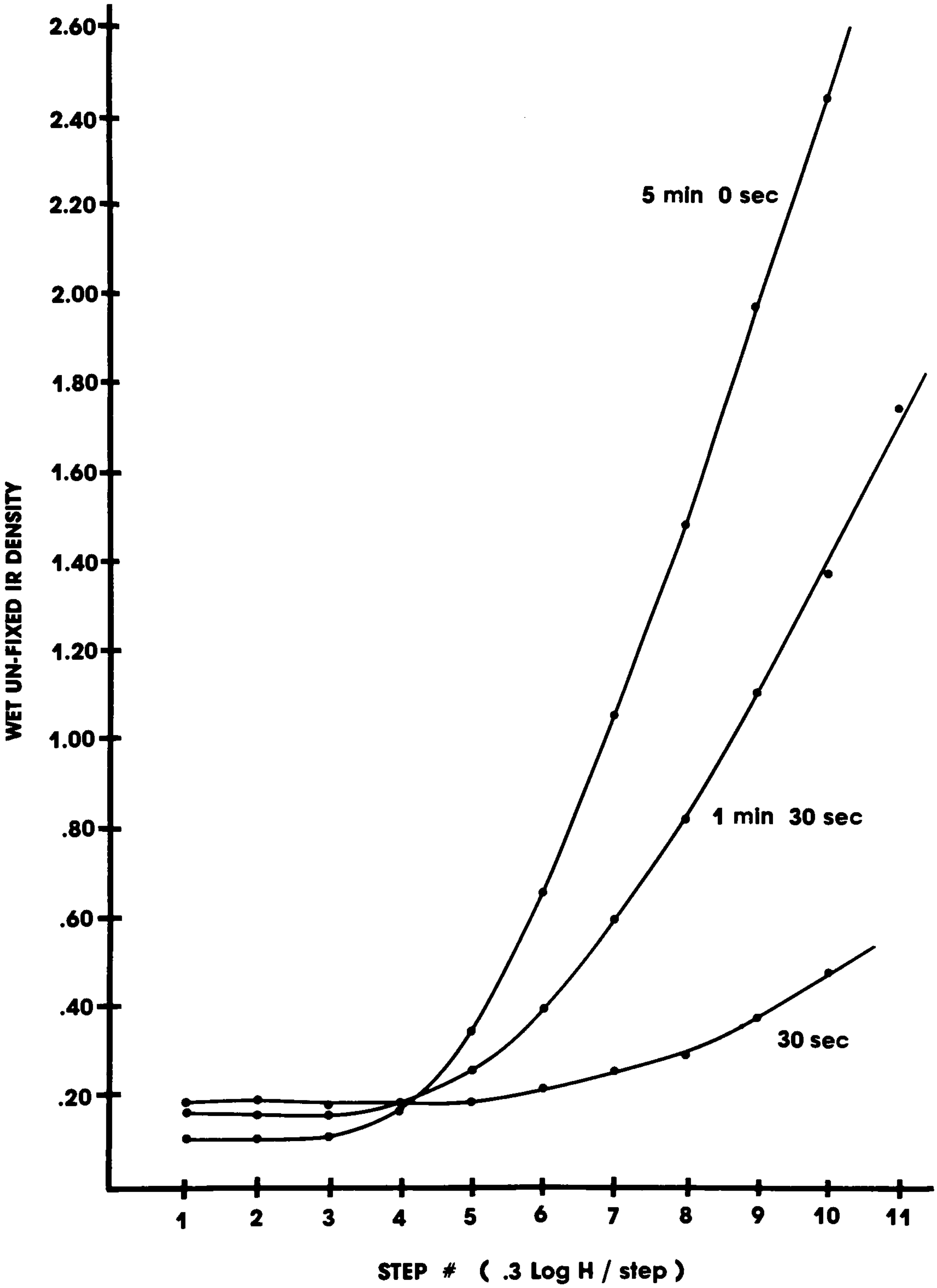

Figure 9 : Density as a function of Log exposure for Eastman Kodak Fine Grain Release Positive, type 5302, developed in D-76.

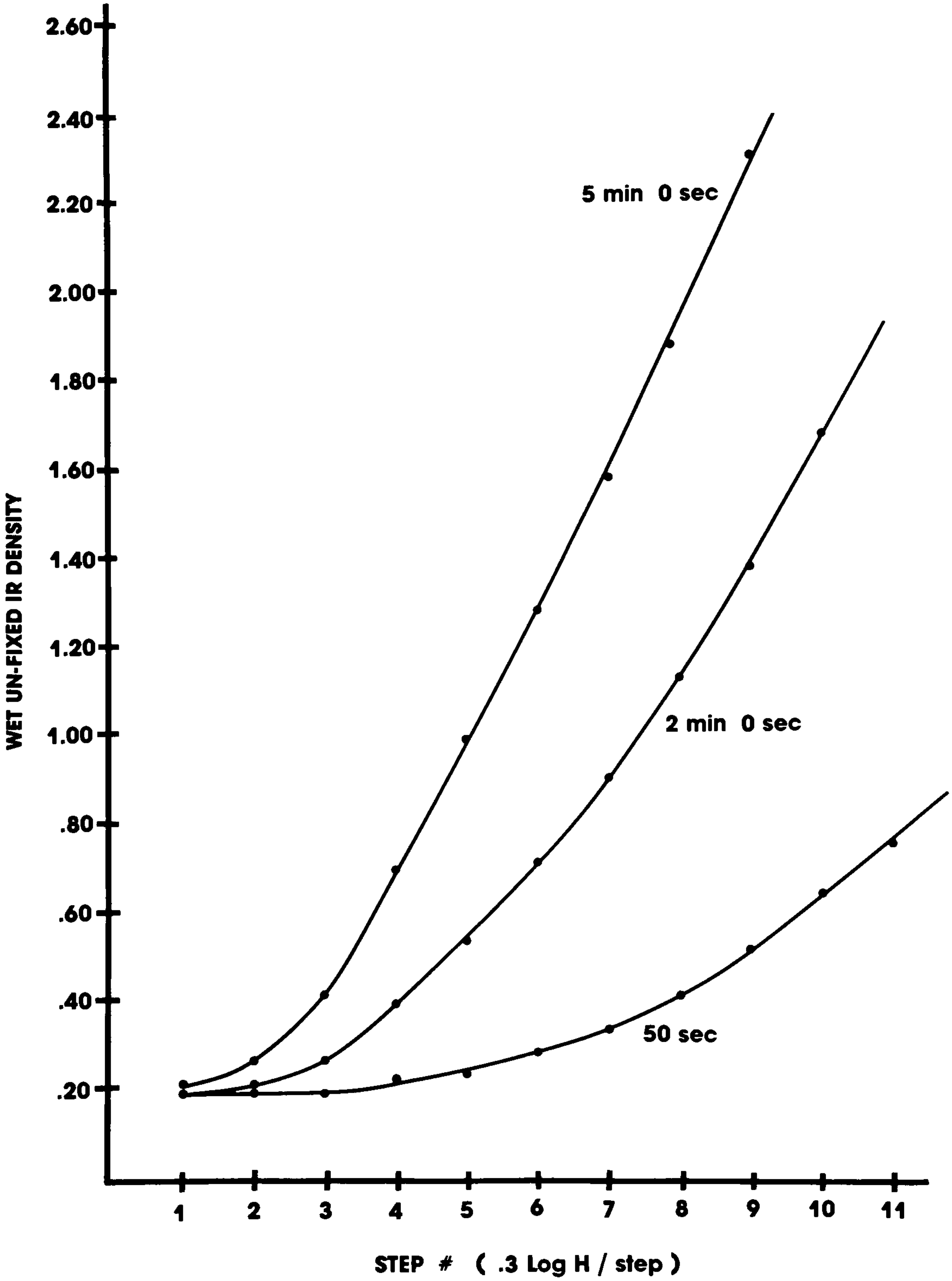

Figure 10 : Density as a function of Log exposure for Eastman Kodak Commercial Film, type 6127, developed in D-76.

this process, but the linearity between the two types of densities is clearly shown.

The last graph for this series, figure 14, shows both wet and dry D-Log exposure curves for a single film sample after 5 minutes of development. Agreement between the two curves is good with the largest error occurring in the base plus fog portion of the curves. Whenever wet IR density and dry diffuse density are plotted together like this, the wet IR density will always be somewhat higher in the toe region. This again is probably due to the increase in scattering from water absorption combined with the fact that the device is calibrated with a dry film base sample (refer to the Software Calibration section contained in the operating manual for details). Another intresting point is that the two curves cross one another close to a density of .70. This is the density of the mid-point calibration sample used at the start of the process. At and around densities of .70, the calibration routine used by the IR densitometer forces differences nearly to zero.

Series 2:

Eastman Kodak Fine Grain Release Positive, type 5302, was processed in D-76 at 70° F for 5 minutes. Sensitometery consisted of film samples being exposed in a Kodak model 101 sensitometer. A Kodak #5 step tablet was used along with a 0.78 Inconel N.D. filter. The sensitometer provided 340 lux·seconds at the wedge. Three runs were made with fresh developer and rinse water. Scans were taken once per second for the first minute, then once every 10 seconds for the remaining 4 minutes. No scans were taken during the one minute rinse that followed development.

All processing was done under Kodak 1A safelight conditions. After the water wash, film samples were tray-fixed for five minutes then washed for twenty minutes and dried.

Results from the first run of this second series are shown in figure 9. Wet, un-fixed IR density is plotted as a function of step # (actual Log exposure values can be found at the end of this section). Curves after 30 seconds, 1 minute 30 seconds, and 5 minutes of processing are shown, with the 5 minute curve being the last one obtained before the water wash.

The IR densitometer reported an initial density of approximately .18 due to the usual emulsion swelling from developer absorption. This is not considered to be significantly different from what was observed in series 1 where D-19 was used. These curves appear typical, but once again something unusual is happening in the toe region. The curves show a decrease in base plus fog density with increased development time. This decrease in toe densities is probably due to the slight fixation of the film sample by the developer. D-76 has a relatively high sulfite content (100 g/l)[11], and sulfite is a well-known silver-halide solvent.

Figure 12 shows un-fixed, wet IR density plotted against fixed-out dry diffuse density. These data were obtained after five minutes of development, which is always the last scan taken. More data points are present in this plot because the contrast for this process was lower. There also seems to be a slight S-shape to this plot, but a straight line fit still works well if errors less than +/- .03 D are acceptable. Straight lines have been fitted to the three graphs of this type. If the plot is extended, it will intercept the x-axis at approximately .1 dry diffuse density units. The reason for this probably lies with the calibration routine used, and the fact that zero density is derived from a dry film sample.

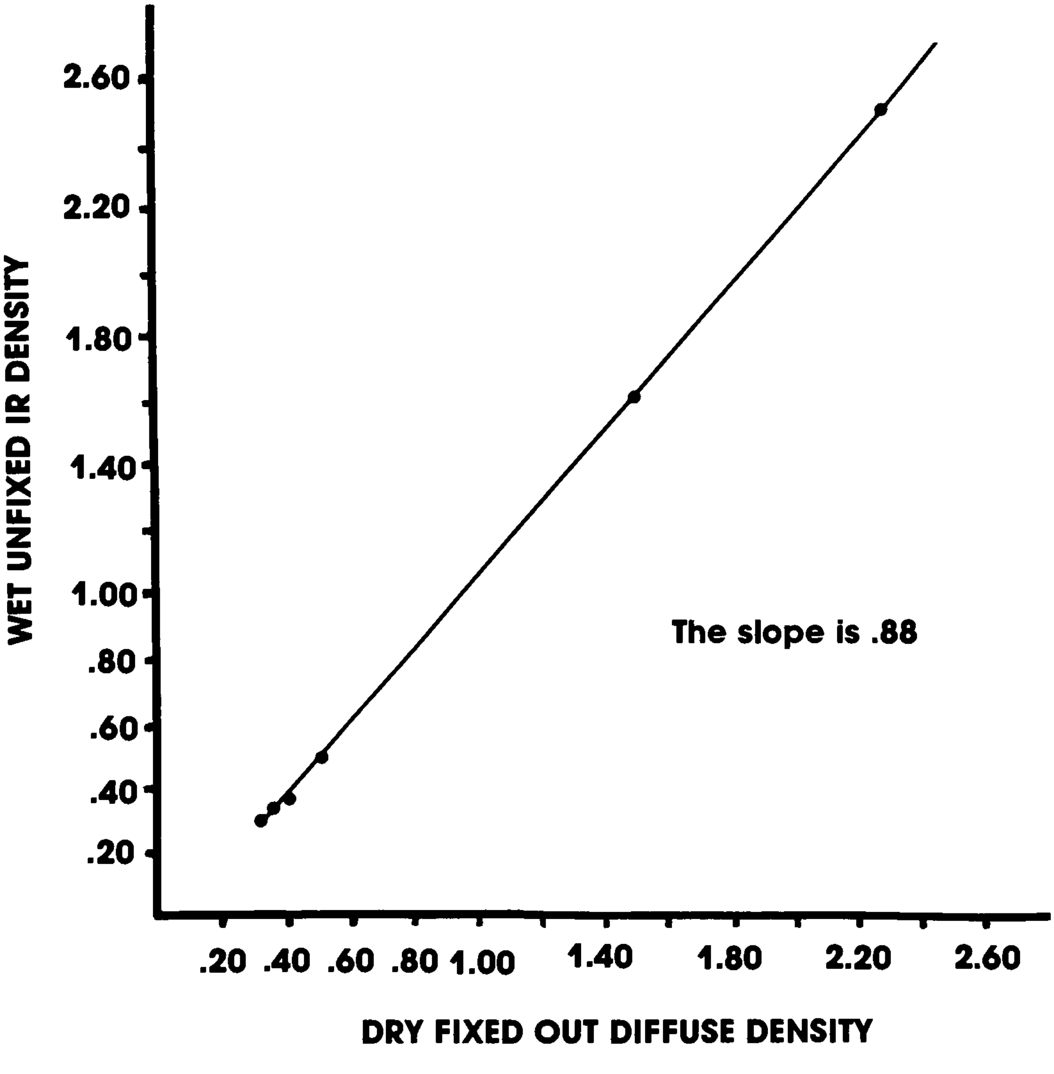

Figure 11 : Unfixed, wet IR density vs. fixed out, dry diffuse density for Fine Grain Release Positive in D-19.

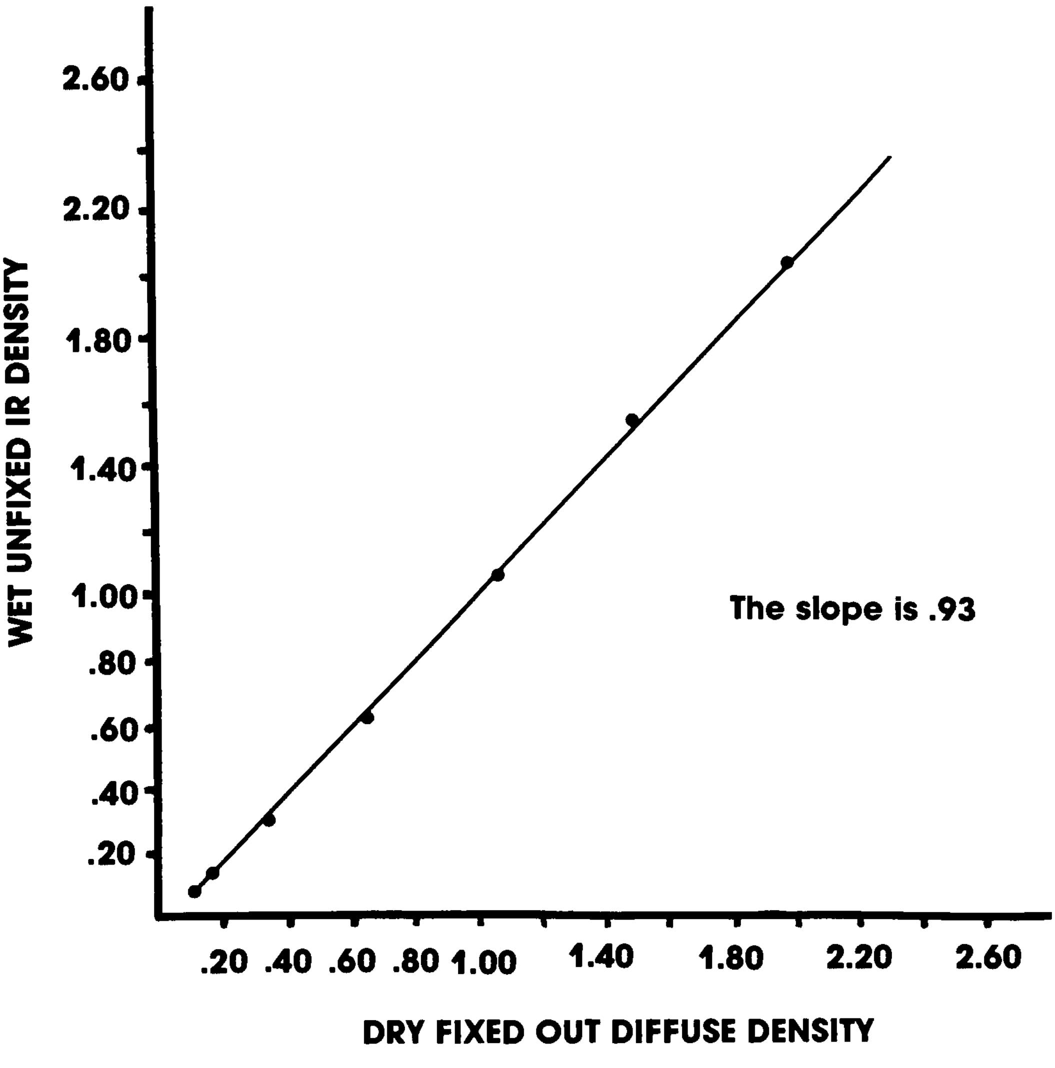

Figure 12 : Unfixed, wet IR density vs. fixed out, dry diffuse density for Fine Grain Release Positive in D-76.

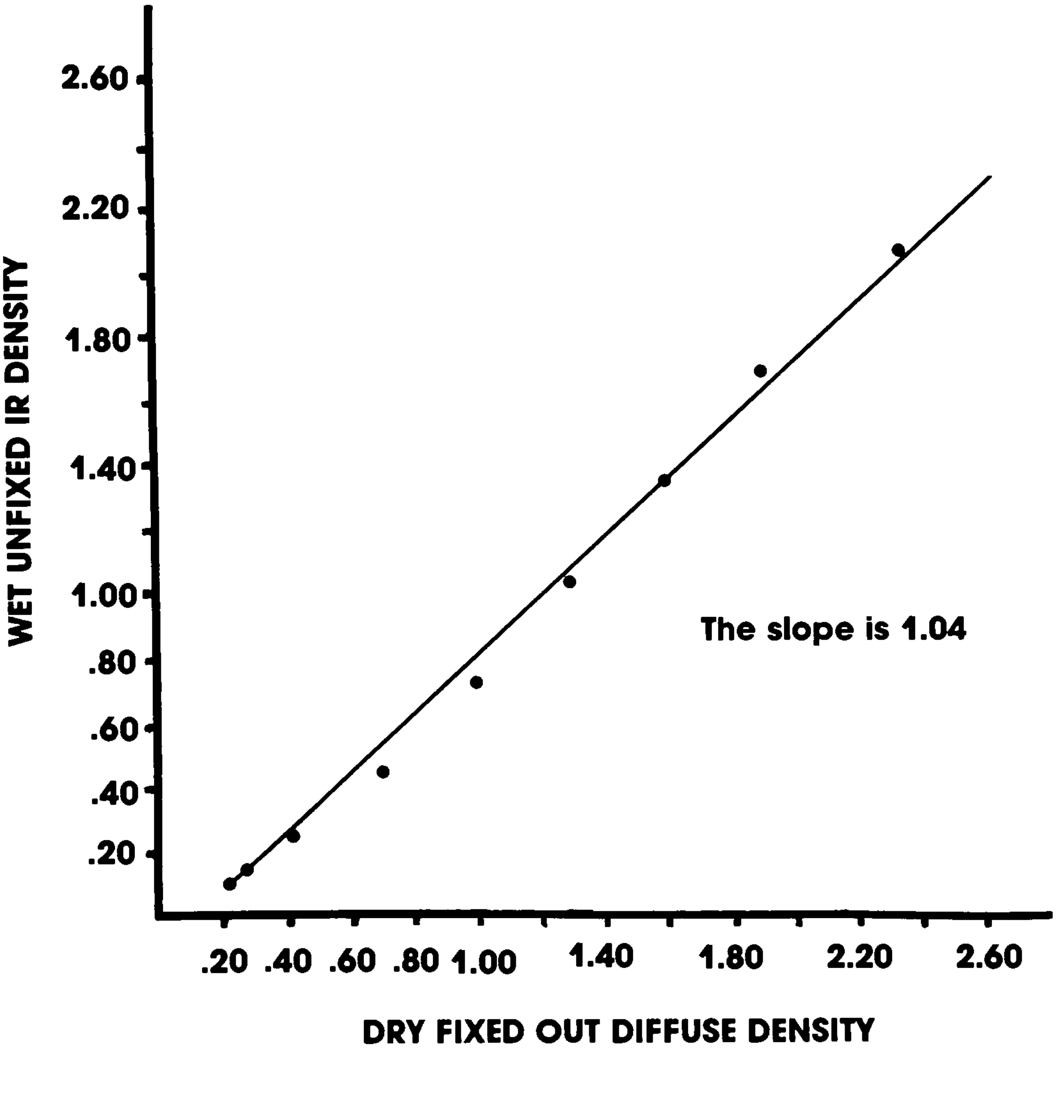

Figure 13 : Unfixed, wet IR density vs. fixed out, dry diffuse density for Commercial Film, type 6127, in D-76.

The last graph for this series, figure 15, shows both wet and dry D-Log exposure curves for the same film sample after 5 minutes of development. This time the curves cross around .80, but the reason is still probably due to the calibration routine. For the toe region of the curve, the comments made about figure 14 apply here also.

<u>Series 3:</u>

Eastman Kodak Commercial Film, type 6127, was processed in D-76 at 70° F for five minutes. Sensitometry consisted of film samples being exposed in a Kodak model 101 sensitometer. A Kodak #5 step tablet was used along with a 1.20 Inconel N.D. filter. The sensitometer provided 340 lux·seconds at the wedge. Three runs were made with fresh developer and rinse. Scans were programmed just as they were in the first two series. Darkroom conditions and fixing procedures were the same as used in the first two series.

Results from the first run of this third series are shown in figure 10. Wet, un-fixed IR density is plotted as a function of step number (actual Log exposure values for each step number can be found at the end of this section). Curves after 50 seconds, 2 minutes, and 5 minutes of processing are shown, with the 5 minute curve being the last one obtained before the water wash.

The IR densitometer reported an initial density of approximately .19 due to the usual absorption of developer. This "wet emulsion density" was noted to be just about the same for all three series run. The amount of time after the start of processing it took to reach this density was about the same for all three series also (5 to 9 seconds).

The curves in figure 10 show very little increase or decrease in base plus fog density with increased development time. It might help to explain this by breaking the development of the toe region into two competing processes. The first process is the reduction of silver-halide to silver metal. This, of course, produces density, and may be brought about by the development of latent image centers, or the random development of silver halide crystals to produce fog. The second process is the slight fixation of the film by the high sulfite developer. This would cause a reduction in density as the effect of scattering would decrease.

For the film/developer combinations considered here, these two competing processes have various outcomes. The first was Fine Grain Release Positive developed in D-19. Toe densities increased with time because D-19 is an active developer and fog production outweighed fixation. The second combination was Fine Grain Release Positive in D-76. D-76 is a milder developer than D-19 and fixation proceeded faster than fog and an overall decrease in toe densities was observed. The last combination was Commercial Film developed in D-76. Toe densities were noted to remain relatively constant for this series. A probable reason is Commercial Film is coarse grained compared to Fine Grain Release Positive and has almost twice as much silver[12]. Perhaps this extra amount of silver halide (coated in two coats), along with the use of the milder D-76 produced a stalemate between the two processes described above. That is, perhaps the rate of density decrease due to fixation was equalled by the rate of increase of density by fog production and therefore little or no net change in toe density resulted.

Figure 13 shows un-fixed, wet IR density plotted against fixed-out, dry diffuse density. Again a straight line can be fit to the data, but the s-shape is more pronounced in this plot than any of the others. It is felt that a linear model is still a good choice to describe the relationship, but further study is indicated. It is interesting to note that this same type of S-shaped relationship appeared in early studies by M. Piskacek[8] in 1976.

The last graph of this series, figure 16, shows both wet and dry D Log exposure curves for the same film sample after 5 minutes of development. The slopes of the two curves are roughly parallel and therefore differ mostly by some additive constant. This constant is probably due to the base plus fog density remaining almost constant through out the process as was explained earlier. This is only supposition, and further study is indicated.

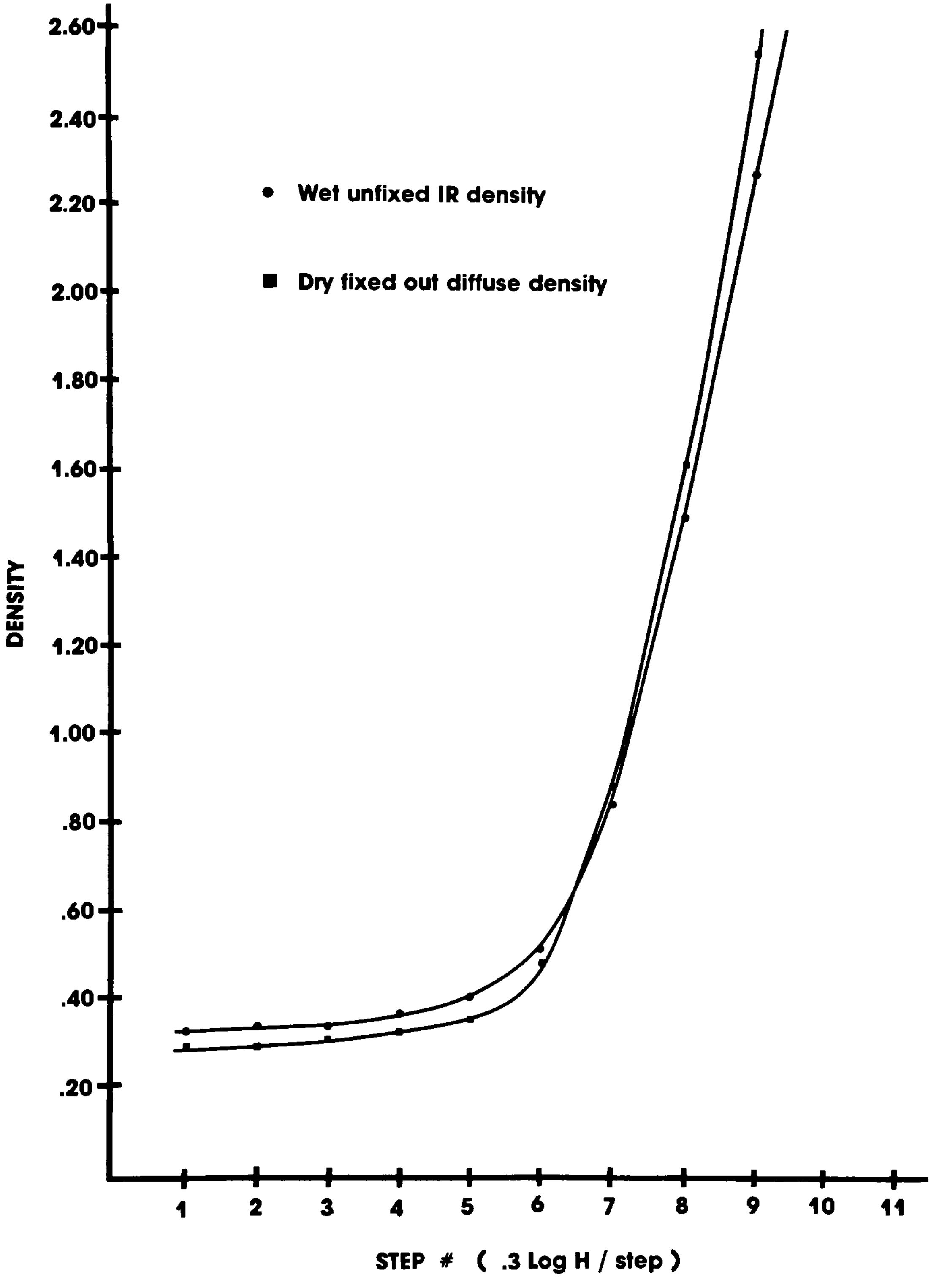

Figure 14 : Comparison of D-Log H curves for wet unfixed, and dry fixed out Fine Grain Release Positive in D-19.

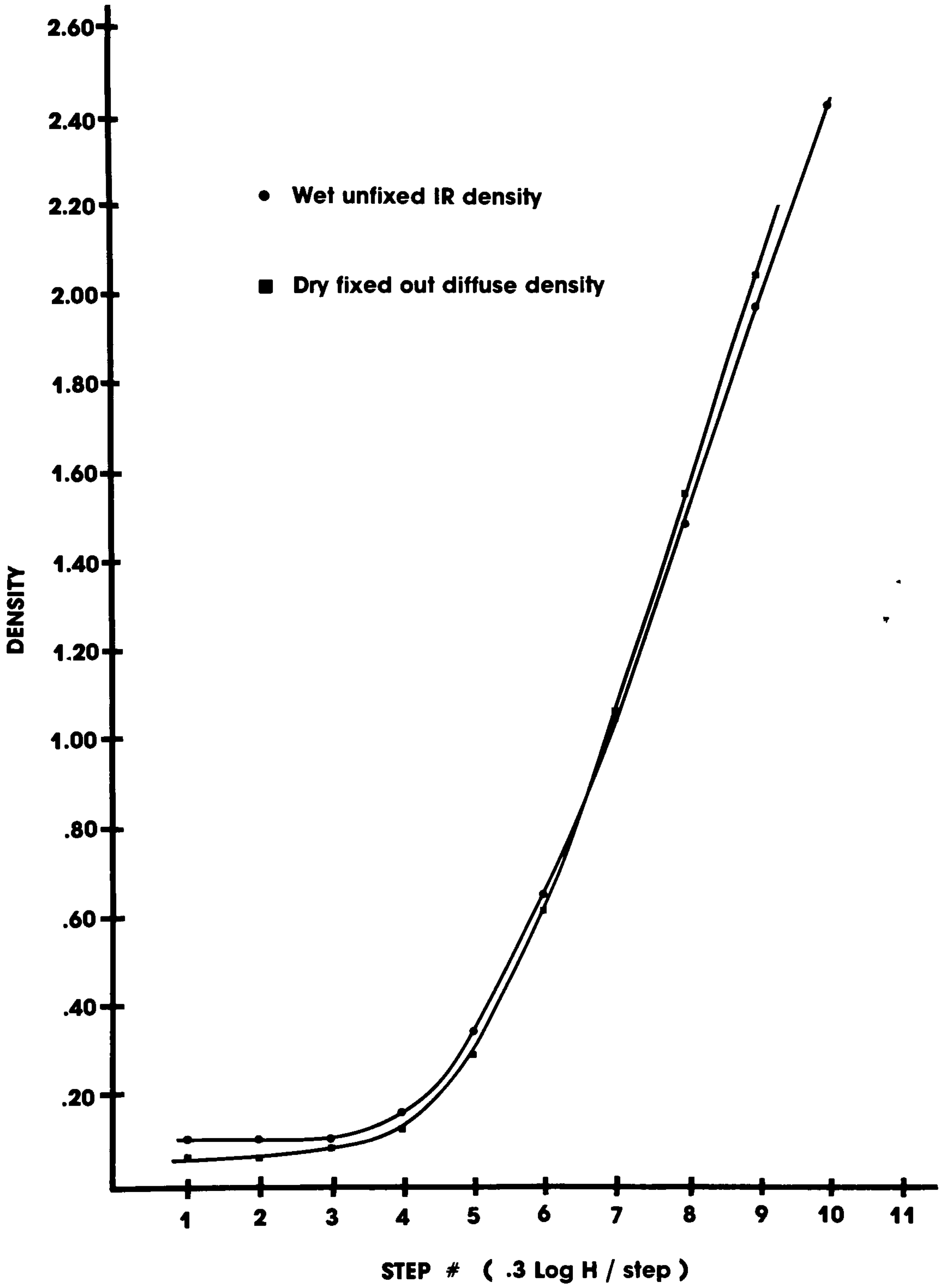

Figure 15 : Comparison of D-Log H curves for wet unfixed, and dry fixed out Fine Grain Release Positive in D-76.

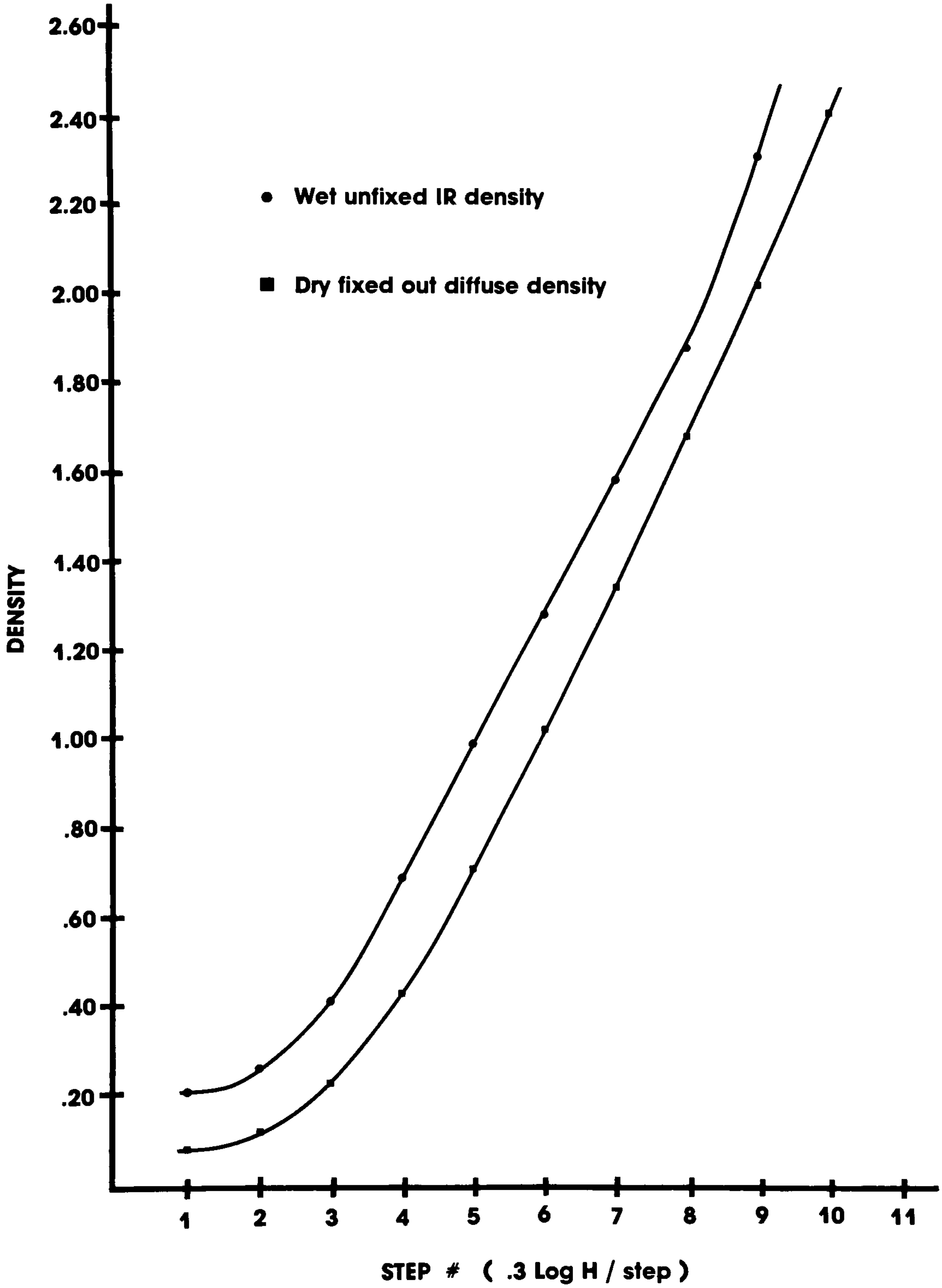

Figure 16 : Comparison of D-Log H curves for wet unfixed, and dry fixed out Commercial film, type 6127, in D-76.

Repeatability Study:

From each of the three different film/developer combinations, three sets, or replications, were obtained. Recall from the scan programming used, 100 scans were made during each process run. As there were 3 replications of each of the 3 series, this makes for a total of 900 scans being taken! Of the 100 scans taken for each process, 8 were selected as being represenative, and are listed as raw data in the appendix (for a total of 72 scans for all 3 series). To be able to make statements about the repeatability of the device, the 8 scans recorded were taken at the same time within each process. Of these 8 scans taken, 3 from each process run are used in the following analysis. The three elasped times selected correspond to the ones used for plotting the family of curves shown in figs. 8, 9, and 10.

Table 1 is data from series 1. The data are grouped as to when during development they were acquired. The first column on the left is the step number. As the step numbers increase, so does the amount of exposure that particular step received, and hence an increase in density is noted. The next three columns are the replicated data sets for the development time under study. The next $\overline{D}$ gives the average density of each step for all three replicates, followed by the sample standard deviation, S_D, for each step. The last column is simply $D_{max} - D_{min}$ for the three readings taken at each step just to give some idea of what the data spread is. Table 2 is for data taken during series 2 and table 3 is for data taken during series 3.

Tables 4 and 5 show data taken from a fourth run not mentioned earlier. This data was taken as a fourth replicate of experimental series 1 and 2, but with one major difference; these samples were processed <u>without</u> a fresh change of developer. Also, the tubes leading to the development chamber were not given a chance to drain, as had been the case between all other process runs. The purpose of this is to demonstrate what effect on data repeatability using developer warmed by an earlier process run can have. It was noted that after a process run, the developer temperature would be 2 or 3 degrees higher that at the start of processing. Therefore, an increase in density due to an increase in temperature can be expected. The data in these two tables support this statement. Average density, $\overline{D}$, and the sample standard deviation, S_D, are included to show that the increase is a real one and not simple variability within the process.

Repeatability study: Series 1

Table 1 : Repetition data for Fine Grain Release Positive developed in D-19.

5 min 0 sec

Step #	Rep 1	Rep 2	Rep 3	$\bar{D}$	S_D	Spread
1	.32	.30	.33	.32	.015	.03
2	.33	.30	.33	.32	.017	.03
3	.33	.31	.33	.32	.012	.02
4	.36	.34	.36	.35	.012	.02
5	.40	.36	.40	.39	.023	.04
6	.51	.51	.51	.51	0	0
7	.84	.80	.87	.84	.035	.07
8	1.49	1.43	1.50	1.47	.038	.07
9	2.27	2.24	2.31	2.27	.035	.07
10	2.94	2.90	2.93	2.92	.020	.04
11	3.08	3.06	3.08	3.07	.012	.02

2 min 0 sec

Step #	Rep 1	Rep 2	Rep 3	$\bar{D}$	S_D	Spread
1	.19	.18	.19	.19	.006	.01
2	.20	.17	.19	.19	.015	.03
3	.20	.19	.19	.19	.006	.01
4	.22	.21	.22	.22	.006	.01
5	.24	.22	.23	.23	.010	.02
6	.29	.31	.30	.30	.010	.02
7	.46	.45	.50	.47	.026	.04
8	.87	.86	.89	.87	.015	.03
9	1.47	1.42	1.48	1.46	.032	.06
10	2.15	2.09	2.17	2.14	.042	.06
11	2.60	2.56	2.61	2.59	.026	.05

Series 1 (con't)

30 sec

Step #	Rep 1	Rep 2	Rep 3	$\overline{D}$	S_D	Spread
1	.17	.17	.17	.17	0	0
2	.17	.16	.18	.16	.010	.02
3	.18	.18	.17	.18	.006	.01
4	.19	.19	.19	.19	0	0
5	.20	.18	.19	.19	.010	.02
6	.20	.23	.21	.21	.015	.03
7	.24	.25	.28	.26	.021	.04
8	.38	.39	.41	.39	.015	.03
9	.64	.59	.60	.61	.026	.06
10	.91	.86	.89	.89	.025	.05
11	1.17	1.10	1.17	1.15	.040	.07

Repeatability study: Series 2

Table 2: Repetition data Fine Grain Release Positive developed in D-76.

5 min 0 sec

Step #	Rep 1	Rep 2	Rep 3	$\bar{D}$	S_D	Spread
1	.10	.08	.08	.09	.012	.02
2	.10	.10	.08	.09	.012	.02
3	.10	.10	.09	.10	.006	.01
4	.16	.16	.15	.16	.006	.01
5	.34	.33	.33	.33	.006	.01
6	.65	.64	.65	.65	.006	.01
7	1.05	1.07	1.07	1.06	.012	.02
8	1.48	1.50	1.50	1.49	.012	.02
9	1.97	1.99	1.98	1.98	.010	.02
10	2.42	2.47	2.46	2.45	.026	.03
11	2.72	2.74	2.80	2.75	.042	.08

1 min 30 sec

Step #	Rep 1	Rep 2	Rep 3	$\bar{D}$	S_D	Spread
1	.16	.15	.14	.15	.010	.02
2	.17	.17	.13	.16	.023	.04
3	.15	.16	.13	.15	.012	.03
4	.18	.20	.16	.18	.020	.04
5	.25	.23	.24	.24	.010	.02
6	.39	.38	.40	.39	.010	.02
7	.59	.59	.60	.59	.006	.01
8	.81	.83	.82	.82	.010	.02
9	1.10	1.12	1.10	1.11	.012	.02
10	1.37	1.37	1.37	1.37	0	0
11	1.54	1.57	1.56	1.56	.015	.03

Series 2 (con't)

30 sec

Step #	Rep 1	Rep 2	Rep 3	$\bar{D}$	S_D	Spread
1	.18	.17	.17	.17	.006	.01
2	.19	.20	.16	.18	.020	.04
3	.16	.19	.16	.17	.017	.03
4	.18	.20	.17	.18	.015	.03
5	.17	.17	.16	.17	.006	.01
6	.21	.19	.22	.21	.016	.03
7	.25	.23	.25	.24	.012	.02
8	.28	.32	.29	.30	.021	.04
9	.37	.39	.38	.38	.010	.02
10	.47	.44	.47	.46	.017	.03
11	.50	.54	.51	.52	.021	.04

Repeatability study: Series 3

Table 3: Repetition data for Commercial Film developed in D-76.

5 min 0 sec

Step #	Rep 1	Rep 2	Rep 3	$\bar{D}$	S_D	Spread
1	.21	.20	.21	.21	.006	.01
2	.26	.26	.26	.26	0	0
3	.41	.41	.41	.41	0	0
4	.69	.68	.69	.69	.006	.01
5	.99	.98	.99	.99	.006	.01
6	1.28	1.27	1.29	1.28	.010	.02
7	1.58	1.55	1.58	1.57	.018	.03
8	1.88	1.87	1.89	1.88	.010	.02
9	2.31	2.30	2.33	2.31	.015	.03
10	3.32	3.75	3.49	-	-	-
11	3.76	3.76	3.76	-	-	-

2 min 0 sec

Step #	Rep 1	Rep 2	Rep 3	$\bar{D}$	S_D	Spread
1	.19	.18	.19	.19	.006	.01
2	.21	.19	.21	.20	.012	.02
3	.26	.26	.26	.26	0	0
4	.39	.37	.38	.38	.010	.02
5	.53	.52	.54	.53	.006	.02
6	.71	.70	.73	.71	.015	.03
7	.90	.89	.93	.91	.020	.04
8	1.13	1.13	1.16	1.14	.017	.03
9	1.38	1.38	1.42	1.39	.023	.04
10	1.68	1.69	1.73	1.70	.026	.05
11	1.96	1.97	2.03	1.99	.038	.07

Series 3 (con't)

50 sec

Step #	Rep 1	Rep 2	Rep 3	$\bar{D}$	S_D	Spread
1	.19	.18	.19	.19	.006	.01
2	.19	.18	.19	.19	.006	.01
3	.19	.19	.19	.19	0	0
4	.22	.20	.21	.21	.010	.02
5	.23	.22	.24	.23	.010	.02
6	.28	.26	.29	.28	.015	.03
7	.33	.33	.35	.34	.012	.02
8	.41	.41	.44	.42	.017	.03
9	.51	.52	.55	.53	.021	.04
10	.64	.67	.69	.67	.025	.05
11	.75	.77	.81	.78	.031	.06

Repeatability study: Series 1

Table 4 : Process data for Fine Grain Release Positive developed in D-19 demonstrating effect of developer heating.

5 min 0 sec

Step #	$\bar{D}$	S_D	Spread	Run#4	$D_i-\bar{D}$
1	.32	.015	.03	.36	.04
2	.32	.017	.03	.36	.04
3	.32	.012	.02	.38	.06
4	.35	.012	.02	.38	.03
5	.39	.023	.04	.43	.04
6	.51	0	0	.56	.05
7	.84	.035	.07	.94	.10
8	1.47	.038	.07	1.61	.14
9	2.27	.035	.07	2.40	.13
10	2.92	.020	.04	3.07	.15
11	3.07	.012	.02	3.12	.05

2 min 0 sec

Step #	$\bar{D}$	S_D	Spread	Run#4	$D_i-\bar{D}$
1	.19	.006	.01	.22	.03
2	.19	.015	.03	.20	.01
3	.19	.006	.01	.22	.03
4	.22	.006	.01	.23	.01
5	.23	.010	.02	.23	0
6	.30	.010	.02	.32	.02
7	.47	.026	.04	.54	.07
8	.87	.015	.03	.96	.09
9	1.46	.032	.06	1.59	.13
10	2.14	.042	.06	2.29	.16
11	2.59	.026	.05	2.75	.16

Repeatability study: Series 2

Table 5: Process data for Fine Grain Release Positive developed in D-76 demonstrating the effect of developer heating.

5 min 0 sec

Step #	$\bar{D}$	S_D	Spread	Run#4	$D_i - \bar{D}$
1	.09	.012	.02	.09	0
2	.09	.012	.02	.10	.01
3	.10	.006	.01	.10	0
4	.16	.006	.01	.17	.01
5	.33	.006	.01	.36	.03
6	.65	.006	.01	.68	.03
7	1.06	.012	.02	1.11	.05
8	1.49	.012	.02	1.54	.06
9	1.98	.010	.02	2.02	.04
10	2.45	.026	.03	2.50	.05
11	2.75	.042	.08	2.85	.10

1 min 30 sec

Step #	$\bar{D}$	S_D	Spread	Run#4	$D_i - \bar{D}$
1	.15	.010	.02	.15	0
2	.16	.023	.04	.16	0
3	.15	.012	.03	.14	-.01
4	.18	.020	.04	.19	.01
5	.24	.010	.02	.26	.02
6	.39	.010	.02	.42	.03
7	.59	.006	.01	.64	.05
8	.82	.010	.02	.88	.06
9	1.11	.012	.02	1.16	.05
10	1.37	0	0	1.43	.06
11	1.56	.015	.03	1.64	.08

Uniformity of Development:

The Fluid Transport System (FTS), which includes the chamber, pump, tubing and valves, presented some of the most complex design problems encountered in the project. The most important question was; would the flow of developer through the development chamber give uniform development, or would there be some type of directional effect. The problem is really one of hydraulics, and therefore, design procedures are not always as straightforward as one would like. The main design criterion was to produce a laminar flow of fluid through the chamber. Laminar flow is the smooth, uniform movement of fluid that is free of turbulence and bubbles.

To determine what level of development uniformity could be obtained once the FTS was actually constructed, the following experiment was performed.

1.) Samples of Eastman Kodak Pan-X Recording Film, Type SO-164, were given two levels of uniform exposure. The first set were exposed to room lighting for five minutes to give a developed density of 2.4. The second set received their exposure from an open-gated Durst enlarger. The level of exposure was enough to produce a developed density of approximately 1.5.

2.) All samples were developed in D-76 at 68° F for 5 minutes. Development was followed by a one minute rinse, then by a two minute fix. Samples were then washed and dried in the normal manner.

3.) The pump used by this system has 7 different speed settings (see Figure 20 for flowrate characteristics). This is about the only variable over which the user of the IR densitometer has control when it comes to flow studies. Therefore, the uniformly exposed samples from above were each developed at a different flowrate.

The results of this experiment are shown in figures 17 and 18. Figure 17 shows dry, fixed-out diffuse density as a function of position for the sample that received the room light exposure. The position marked "IN" is where the developer first enters the chamber and strikes the film sample. The first density reading is taken there. The next four readings are taken at equally spaced intervals along the detector region, i.e. the region of the sample where the eleven IR densitometers are located. The last reading called "OUT" is from the area just below the chamber exit port. Figure 18 showns the same type of graph, but for the samples exposed for a developed density of approximately 1.5.

The data presented here is not exhaustive, but general statements about uniformity of development can be made. The data suggest that as the flowrate of developer is increased through the chamber, directional effects begin to decrease. However, this same increase in developer flowrate also causes an increase in the overall density of the film sample. This all sounds reasonable as one would expect an increase in developer flow to bring in fresh developer faster <u>and</u> remove development by-products that could retard development. Another general effect is that densities always are somewhat higher where the developer enters and somewhat lower where it exits. This is really not of much concern as the graphs tell us that if the pump flowrate is made high enough, very uniform development down the length of the film where the eleven densitometers read can be obtained. Also, figure 18 seems to show that even better uniformity can be achieved as the overall exposure level is reduced. This again sounds reasonable because as the exposure level is decreased, one would expect the amount of developer by-products to decrease and therefore directional effects should lessen.

Lastly, if uniformity is critical, users may wish to perform more exacting uniformity experiments for their particular film/developer combination. They could then possibly generate a methodology for correcting their raw data for directional effects.

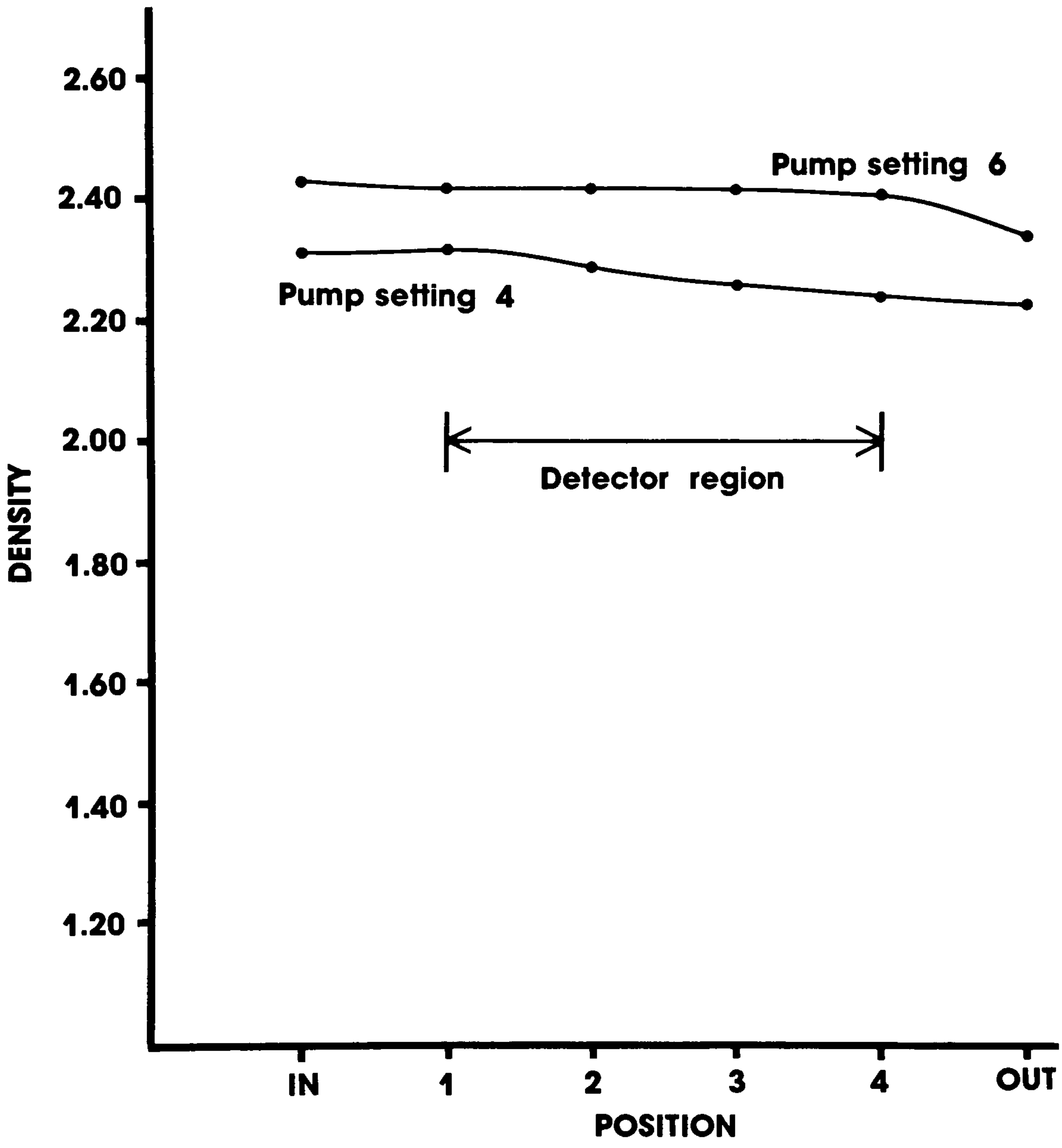

Figure 17 : Density as a function of position and flow rate for a sample of Pan-X Recording Film, SO-164, exposed to room lights for 5 minutes and developed in D-76.

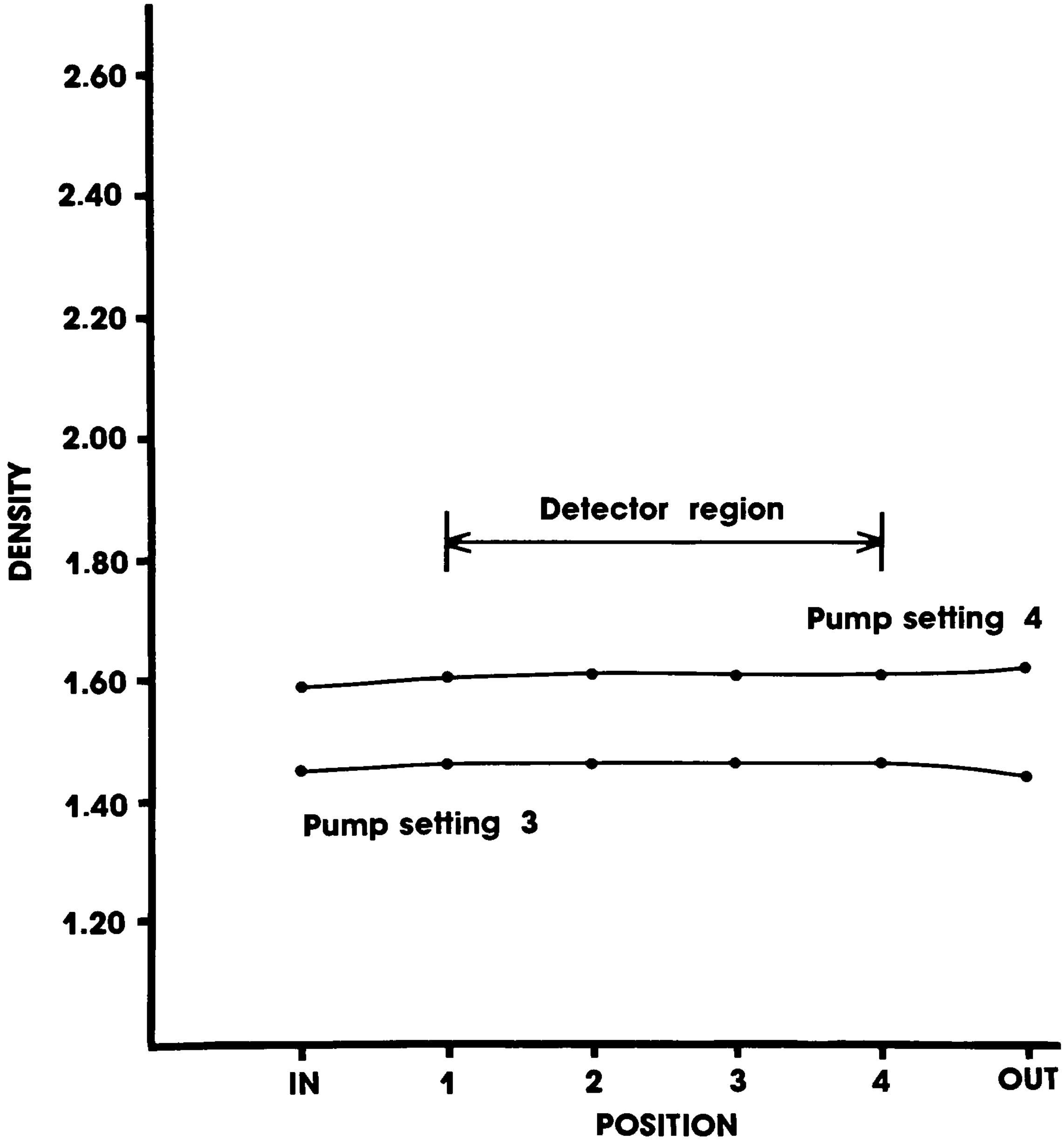

Figure 18 : Density as a function of position and flow rate for a uniformly exposed sample of Pan-X Recording Film developed in D-76.

Experimental Conclusions and Recommendations:

As should be obvious by now, the amount of additional research that could be performed on the IR densitometer is tremendous. However, it is felt that enough data has been collected to allow some generalized statements about it's performance to be made.

First, the assumption that an approximately linear relationship exists between wet, un-fixed IR density and dry, fixed-out diffuse density seems reasonable. More study is indicated in this area, with particular focus on what is happening optically to a wet, developing emulsion. Perhaps experiments should be conducted with software calibrations being performed when film samples are wet instead of dry, as is now currently recommended. Also, all experiments were performed with the anti-halation backing untouched. Although the backside of the film is never wetted during processing, perhaps the infrared radiation has some effect on the backing that could degrade density readings later on in the process.

Second, the run-to-run repeatability of the device is considered to be very good. The data from tables 1, 2, and 3 seem to indicate that the best repeatability is obtained at lower densities. As an example, the device is able to hold an average repeatability of +/- .02 out to a density of .50 for all three series, or a variability of approximately 5%. This value becomes only +/- .03 out to a density of 2.5. Also observed, was that the more active the developer, the poorer the run-to-run repeatability. Other important results from the experiments are the effect on repeatability due to developer temperature variations. It was noted that a five minute development run would raise the temperature of the developer by 2 or 3 degrees. This is due to the heat generated by the pump and valves, and general frictional effects. This rise in temperature is enough to cause a significant increase in density if another process run is made using the same tank of developer. Also, if the tubes leading to the development chamber are not drained between runs, repeatable results are difficult to obtain due to solution carry overs. The full extent of what solution carry over will do, however, is not known and further study is indicated.

Lastly, uniformity of development across the region where the IR densitometers are located seems to be very good and not a source of great concern. There are major directional effects near the edges of the film sample where the O-ring seal is located, but these areas are not seen by the IR densitometers. As was stated earlier, if extreme precision is required, specific studies can be made to better characterize what little non-uniformity there is, and correction procedures can be implemented. Suggested improvements might be a temperature control for the FTS and a pump of higher and more consistent flowrate.

Table 6: Log exposure values used for all experiments.

Sensitometer : Kodak Model 101.
Wedge : Kodak Sensitometric Step Tablet #5, S/N R903-12-2.
Open-gate exposure : 340 lux·seconds.
Neutral density filter type : Inconel

Step	Step Density	Log E w/.78 ND	Log E w/1.20 ND
1	3.07	-1.32	-1.74
2	2.77	-1.02	-1.44
3	2.46	-.71	-1.13
4	2.16	-.41	-.81
5	1.86	-.11	-.53
6	1.54	.21	-.21
7	1.24	.51	.09
8	.94	.81	.39
9	.64	1.11	.69
10	.34	1.41	.99
11	.04	1.71	1.29

In-process IR Densitometer Operating Instructions:

For best results, the user of this device should have a complete understanding of its operating principles. Not only does this involve just knowing how to make the device run, but also a thorough knowledge of how the densitometer works.

This operations manual has been broken up into six main function groups. They are:

A.) Emitter calibration.
B.) Software calibration.
C.) Film sample preparation.
D.) Data entry.
E.) Fluid Transport System (FTS).
F.) Prompt descriptions, and error messages.
G.) Printer Maintenance.

The user should read and understand these instructions and descriptions before attempting to use the densitometer. In this way, the user can be assured the best possible results, and wear and tear on the device can be minimized.

Equipment List:

Below are listed the various components needed to operate the In-process IR Densitometer. Some items are kept with the densitometer and will be found on the lower shelf of the rolling service cart. Other items are of general purpose and will have to be located before operating the device.

Items to be kept with the densitometer:

1. Special two-hole registration punch.
2. Modified head for the Kodak Model 101 sensitometer.
3. Calibration samples.
4. Chamber locking pin.

User supplied items:

1. Voltmeter. Range of 20 volts with accuracy of +/- .02 volt.
2. BNC-to-banana-jack adaptor, or some type of adaptor to fit a female BNC connector to voltmeter being used.
3. Test lead. A clip lead of some sort is neccessay to effect a ground connection between the voltmeter and the chamber support frame.
4. Small screwdriver.
5. Darkroom. The densitometer must be loaded and used in total darkness.
6. Source of fresh water to clean the device when processing is completed.

Procedural Descriptions:

A.) Emitter Calibration

This densitometer system uses gallium arsenide infrared emitting diodes (IREDs) as its primary source of radiation for the measurment of optical transmission, hereafter referred to as "density". As these sources are diodes, their output intensity is a function of the forward current passing through the device, rather than the voltage across the diode.

Two other important considerations must be pointed out before detailing the calibration procedure. The first is the type of detector used with the above emitters. Due to their mode of operation, they can only detect a little more than a three decade change in light with an acceptable signal to noise ratio. The second consideration is the operating principle of the entire IR densitometer itself: the densitometer is to measure density of a piece of film as it develops. This implies that the film sample may still have an anti-halation backing on it while readings are being made. So not only will the density of the developing silver be measured, the infrared density of the wet anti-halation backing will also be measured.

The point to all of this is that the user would like to minimize the effect of the anti-halation backing on the density measurments. At the same time, the user would also like to maximize the dynamic range of the densitometer to allow for density readings of at least 3.00 and still maintain some level of accuracy. Therefore, it is necessary to adjust the output of the IR emitters to compensate for the various types of anti-halation backings likely to be processed by this device.

This is done by placing a sample of the particular film under study, dry and unexposed, into the optical path of each of the eleven emitter/detector pairs. The current passing through each IR diode is then adjusted until the output voltage of the companion detector just begins to saturate. Saturation means the maximum output voltage the device is capable of producing while remaining linear. The exact procedure is outlined below, but in this way each emitter/detector pair is optimized for maximum dynamic range in density.

It should be noted that this method of emitter calibration defines what will be considered zero density. That is, a dry, unexposed piece of raw film stock will have, by definition, zero density. All density measurments are therefore relative to dry unexposed film. However, note that once a film sample becomes wet, it's IR density will increase due to emulsion swelling.

<u>Procedure:</u>

a). With the main power switch in the off position, disconnect the Analog Transmission Signal cable from the back of the control cabinet. This is the black coaxial cable with the large female BNC connector on the end. The control cabinet is throughly labeled and will direct the user to this connector.

b.) This part of the calibration can be performed with just about any type of voltmeter. At the time of this writing, however, a Hewlett-Packard digital voltmeter, (H/P DVM) was available, and thus the procedure will be detailed for this particular type of voltmeter.

Insert the banana-plug-to-BNC adaptor into the H/P DVM. The adaptor should be orientated such that the banana plug marked "COM" fits into the red ground socket on the front panel of the voltmeter. The other plug fits into the red socket marked "VOLTS". <u>DO NOT INSERT BACKWARDS!!</u> To do so will ground the output of the analog multiplexer and destroy it.

c). Connect the Analog Transmission Signal cable to the other side of the BNC-to-banana adaptor. Insert a banana jack test lead into the side of the adaptor marked "COM". Attach the other end to the metal chamber support structure. In this way, an electrial ground path is established between the voltmeter and densitometer.

d). Select the D.C. volts button on the front panel of the DVM. Select the 20 volt range button. Turn the DVM on. Now turn on the main power to the IR densitometer and wait 10 minutes for it to warm up. The DVM should now be reading +15 volts +/- .1. This is a test voltage upon initial power-up. The output of these detectors is directly proportional to the amount of incident flux striking them, therefore, the output is considered a transmission signal.

e). In complete darkness, or under safelight conditions if the film will allow, punch a set of registration holes in a sample of the film type under study. Cut it long enough to cover all eleven detectors, about 8 inches. This is then mounted in the chamber, placing the strip such that the registration holes fit over the two pins at the rear of the chamber. It is most important that the film be mounted emulsion side up, toward the developer channel. Lastly, close the chamber and seal it with the locking pin. The device is now ready to be calibrated.

f). When the main power was first applied, the system came up and prompted: "EMITTER CAL?". If the user is going to process a film type different from that for which the device was last calibrated, an emitter calibration will be necessary. To select the calibrate mode, enter any number from 1-9 , followed by an "E" depression. The system will respond with the prompt: "EMITTER 1". This means that the emitter/detector pair at the top of the chamber (#1) has been activated.

g). The DVM should now be reading some voltage. Adjust the grey trimpot marked #1 located behind the chamber with a small screwdriver until the meter reads approximately 13.0 volts +/- .2 volt. Turn the pot clockwise to increase the voltage. Turn it counter clockwise to decrease the voltage.

h). Press the "E" key and the display will change to: "EMITTER 2". Repeat as above for all eleven emitters. When complete, the system will again prompt: "EMITTER CAL?". To leave this calibration mode, enter zero, followed by "E". This will jump the user to the next prompt.

i). When all eleven emitters have been calibrated, turn the machine off and reconnect the Analog Transmission Signal cable to the control cabinet. Remove the film base sample from the chamber and continue with the software calibration routines.

Note that this emitter calibration will be valid as long as the same type of film is to be used. Turning off the power will not change the settings of the trim pots, therefore, this calibration <u>does</u> <u>not</u> have to be performed each time the device is powered up. The only time the emitters have to be calibrated is when processing a film type different from that for which the device was last calibrated.

B.) Software Calibration:

The basic premise behind the software calibration is that the relationship between wet unfixed IR density and dry, fixed-out diffuse density is a linear one. This important fact was amply demonstrated by M. Piskacek in 1977.

The operation of the software calibration is very straight forward. Certain conditions are established within the development chamber, (detailed below) and a single complete density scan is made. The eleven readings that result are considered to be zero density, and stored in memory as MDO (measured zero density). New conditions are again established within the chamber, this time with a film sample of uniform density large enough to cover all eleven emitter/detector pairs. The density of this sample should be near the mid-point of the maximun density the user expects from the particular film/developer combination under study. For example, if a maximum density of 2.00 is expected, the calibration standard would have a density of 1.00. The density of this sample is known, and entered into the computer as ADMAX (actual maximum density). ADMAX is only a computer variable name, and really refers to mid-range densities. Another complete scan is made and a new set of eleven readings result. These are stored in memory as MDMAX (measured maximum density). With this information now in memory, the computer can now perform eleven seperate linear regressions and generate eleven unique slopes and intercepts for each of the eleven emitter/detector pairs. In this way, as raw data is generated, it is operated on by a first order calibration routine. The final densities viewed later by the user, will have been corrected from wet, IR density to equivalent dry, diffuse density.

Figure 19 shows the relationship between the different variables involved. Calculations performed within the computer are in a 32-bit floating point format. Please consult the Intel Floating Point Arithmetic Library User's Manual for details.

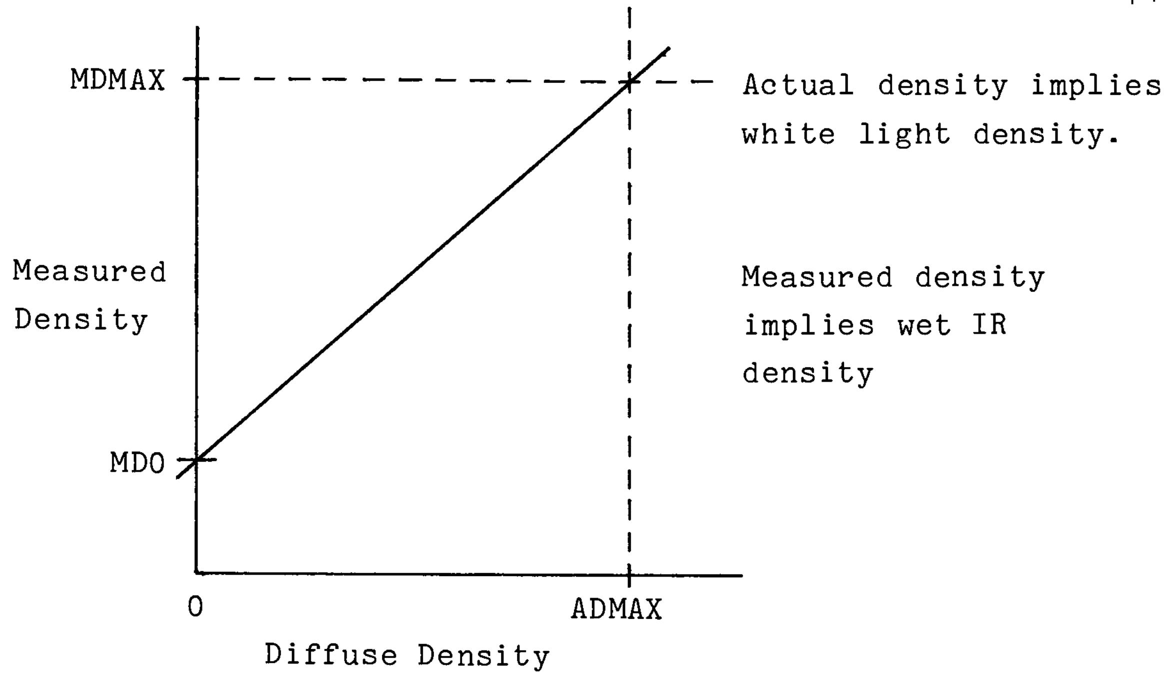

Figure 19: Software Calibration Plot.

<u>MDMAX</u> = Measured maximum density.
<u>ADMAX</u> = Actual maximum density.
<u>MDO</u> = Measured zero density.

Rcall that eleven slope and intercept pairs must be generated for all eleven emitter/detector pairs.

From the plot:

$$MD = (AD) \times (SLOPE) + INTERCEPT$$

and the intercept is simply:

$$INTERCEPT = MDO$$

From another point on the plot:

$$MDMAX = (ADMAX) \times (SLOPE) + MDO$$

Solving for the slope:

$$SLOPE = (MDMAX - MDO) / ADMAX$$

Lastly, corrected densities can be calculated from:

$$AD = (MD - MDO) \times (ADMAX / (MDMAX - MDO))$$

Software Calibration Procedure:

a). This calibration is to be performed after the emitter calibration. If the same type of film base is to be run for this processing session, and no emitter calibration was performed, turn the machine on and allow a 10 minute warm-up before proceeding.

b) Open the chamber door. Make sure the chamber is absolutly clean and dry. Any moisture in the chamber will have an adverse effect on the calibration. Insert the calibration strip into the developer channel. The calibration sample is any material of uniform, known, IR density, close to the mid-point of the expected density range being investigated. Ideally, it should be cut to fit inside the development cavity, up against the IR emitters. It is important that it be placed in the channel so it will not affect the closing of the chamber door. Apply slight pressure to make sure that the strip is seated firmly in the channel.

c). In total darkness, or under safelight conditions if the film will allow, unroll about eight inches of the film under study. Punch two registration holes into one end of the film strip using the special punch provided. Mount the film into the development chamber by aligning the two pins at the rear of the chamber into the holes just punched. Be sure to mount the film emulsion side up, toward the developer channel. Hold the other end of film strip flat against the chamber bottom, close the chamber and seal it with the locking pin.

d.) If the machine has just been turned on, the prompt "EMITTER CAL?" will be on the display. If performing an emitter calibration, complete the calibration and depress the "E" key until this same prompt appears. To get to the software calibration mode, enter zero and depress "E". The system should respond with: "ENTER D-MAX". The user should now enter the value of the calibration sample to be used. Remember that the decimal point is implied. That is, a density of 1.20 is entered as 120. After entering D-max, depress "E". The next prompt will be: "READ D-MAX". The next depression of the "E" key will read the density of the calibration sample <u>plus</u> the density of the dry film base. The value of this reading is assigned the calibration values just entered by the user.

e). The system will now be prompting: "READ ZERO". Open the chamber and carefully remove the calibration sample. Try not to disturb the film sample while doing this. Reseal the chamber door and press the "E" key. The system has now just read the density of the film sample and assigned it the value of zero density.

f). Open the chamber and remove the film base sample. The prompt: "ENTER MONTH" should now be on the display. At this point, the device is 100% calibrated and ready to go.

C.) <u>Film Sample Preparation:</u>

This device was originally designed to measured the density of a film sample that had been exposed to a standard 21-step sensitometric tablet. Alignment proved difficult, however, so a Kodak #5 step tablet is to be used for making all sensi exposures. This tablet has a step increment of about .30 density units, and has been mounted in a standard Kodak 101 sensitometer head. Note that any step tablet can be used, just as long as the step spacing is exactly 10.00 mm, otherwise poor registration of the step exposure to the detectors will give poor results.

Before making any exposures, make sure that this sensitometer head has been obtained! The procedure for making sensitometric exposures is as follow:

a). In complete darkness, unroll about eight inches of the film under study. Use a safelight if the film will allow. Cut the film as close as possible to a right angle with the edge of the film. Punch two registration holes into the film with the punch provided.

b). Align the holes in the film to the pins mounted on the end of the sensitometer head. Mount the film on the head with the emulsion facing the light source. Make the exposure. As with all sensitometer work, the best filter combination will have to be determined by calculation or trial.

c). Mount the exposed sample in the development chamber. The emulsion side always faces up (toward the emitters). Close the chamber and seal it with the locking pin. The film sample is now ready for processing. Remember that the room lights have to remain off while the film is being loaded and processed.

d.) The correct response to the "ENTER MONTH" prompt is to enter the two digit month code followed by an "E" depression. This is repeated for the "ENTER DAY" and "ENTER YEAR" prompts.

e.) The prompt: "MANUAL MODE?" should now be on the display. To select manual mode, enter any number from one to ten followed by an "E" depression. The printer will respond with the heading: "*** MANUAL MODE SELECTED ***". To select automatic, enter zero then a "E" depression. A more detailed description of manual mode and automatic is contained in Section E: Fluid Transport System.

D.) Data Entry:

Other than calibration, the user must also program the IR densitometer with certain process information. The device must be told for how long it is to process film samples and when to take density scans. This is done in the following manner:

a). During the programming stage, the user will receive the prompt: "PROCESS 1=?". The device is asking the user how long to run the first process. There are three tanks and therefore the machine is capable of running three processes. This prompt is answered by entering any number in the range of 0 to 127 minutes. The smallest increment of time is one minute. Invalid entries are flagged as errors (see error message table).

b). As this system has the ability to generate an incredible amount of data, a very selective methodology for the programming of scan acquistion was needed. This was accomplished by breaking each process into a number of smaller intervals. Then for each interval, a rate at which scan data will be acquired is defined. This rate is expressed as the number of scans to be taken <u>per</u> minute, with the range being from 1 scan/minute to 60 scans/minute. It is important to note that the system defines scan rates on a minute by minute basis. This means that for an entered scan rate of 32 scans/minute, the system will round this down to 30 scans/minute and take a scan every 60 / 30 = 2 seconds. This was done because the shortest time for which a scan rate can be defined is one minute.

c). After entering the process length, the system will prompt for the interval length. If an interval length of zero is entered, the device will assume that the user wishes to make no scans during this process and therefore jumps the user to the next process length entry. If scans are to be made, the user should enter an interval length over which data is desired. At all times it should be remembered that the system can store only 187 scans and great care should be exercised not to exceed this value. Also, the entered interval cannot be greater than the process length. Once the interval length has been entered, a scan rate must be entered. The number of scans generated during any interval is simply the interval length times the scan rate. If invalid interval or rate information is entered, error messages will be issued.

d). Interval/rate data can be entered until:

1.) The number of generated scans equals 187.
2.) Ten interval/rate pairs have been entered.
3.) The sum of the interval lengths equals the process length.
4.) An interval length of zero minutes is entered.

e). This procedure is repeated for each of the three processes. If manual mode has been selected, the user is allowed to program only one process as the FTS is under total user control.

Every effort has been made to design the most efficient user interactive operating sysem as possible. There are, however, some ways a user can get into trouble. The most common mistake to be made is to use up all scans before the process is finished. This is done by entering an interval/rate combination that generates many scans. As an example, an interval length of 3 minutes and a rate of 60 scans per minute will produce 180 scans. This does not leave many scans for anything else. Remember that there are a total of 187 scans available and not 187 scans for each process. Once interval/rate information has been programmed, there is no way to clear it and start all over again. Either the device must be turned off and re-started or the programmed data has to be run through. The point is, <u>be</u>

careful when programming scan data!

At the completion of processing, the system will return control to the user with the prompt: "PROCESS #=?". Please refer to the prompt descriptions contained in Section F for directions.

E.) Fluid Transport System (FTS):

The Fluid Transport System, or FTS for short, consists of any component having to do with the transportation of chemistry to and from the development chamber. This system has two modes of operation, automatic and manual. There are certain aspects of this system that require carful attention, and will be repeated through-out this section. The first and formost is; never run the device with the processing tanks empty! To do so will cause excessive wear of the pump gears and shorten pump life. Considerations of the two modes of operations are listed below.

Automatic:

During the programming of the device, the user will receive the prompt: "MANUAL MODE?". To by-pass manual mode and select automatic, the user must enter a zero followed by an "E" depression. Once in automatic mode, the computer will handle the complete operation of the inlet and outlet valves, and the pump. What is not under computer control, however, is the speed of the pump and the detection of fluids within the tanks. These two areas are always the user's responsibility.

To set the pump speed, locate the small knob mounted top dead center over the pump housing. The pump itself is located just below the chamber and right above the chemistry tanks. Refer to figure 20 for flowrate details. Position "0" is off. Position "8" is maximum speed. Best results are obtained at position "7", but the speed selected is up to the user. Tanks should be filled to just below the mounting screws, (about 2 liters) with care being taken to avoid spills onto the control valves. When programming for process lengths while in the automatic mode, the user can run each tank for 127 minutes each. Any combination of tanks can be run, but no tank can be run more than once, and

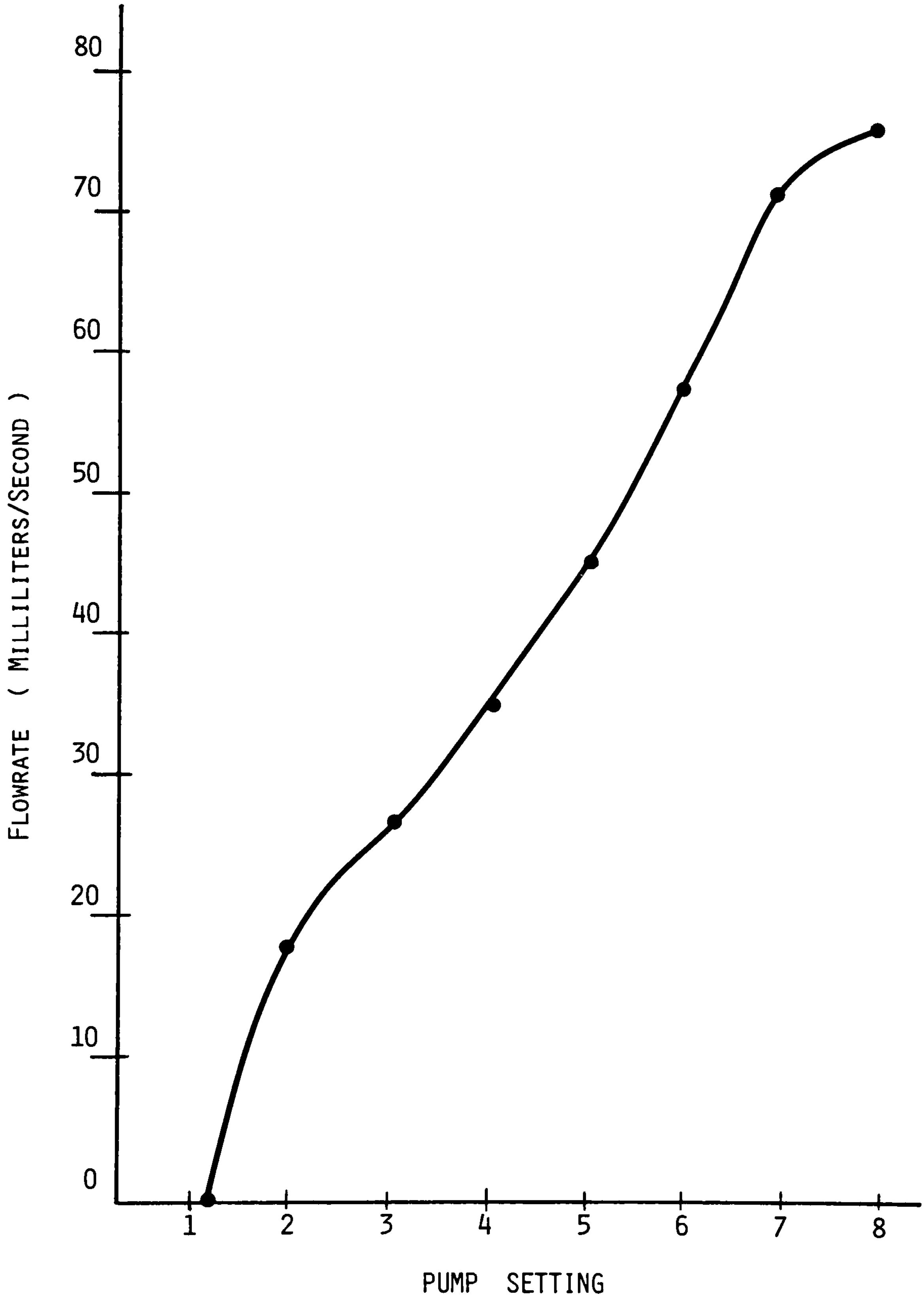

FIGURE 20: FLOWRATE AS A FUNCTION OF PUMP SETTING.

the order of usage is always tank 1, tank 2, tank 3. When the system begins to process, it has no way of knowing if the door to the development chamber is open or not and will always assume that it is closed. There is, however, an interlock switch on the chamber to interrupt the A.C. power to the pump if the door is left open, but the computer does not know this and will always try to start the pump. Even if the door is open, the inlet and outlet valves will open and the programmed timing sequence will begin. To see what exactly is turned on, refer to the FTS relay control box mounted under the cart and to the right. There are three pairs of LEDs and a single red LED at the bottom. The two leftmost red LED pairs are the contol indicators for tank 1 inlet and outlet valves. The center two pairs are for tank 2 and the two on the right are for tank 3. The red LED by itself on the bottom is for the pump. Note that the layout of these LEDs is duplicated on the front panel of the control cabinet. This will be detailed below.

<u>Manual:</u>

To select manual mode, answer the "MANUAL MODE?" prompt by entering any number from 1 to 9 and depress the "E" key. The printer will print ** MANUAL MODE SELECTED ** and the manual FTS control buttons on the front panel of the control cabinet become active. When in manual mode, it is the user's responsibilty to control the switching of tanks and the operation of the pump. This is to allow for the user to switch between any tank as often as desired. Tanks can be mixed, drained, new chemistry can be added, etc. The main purpose is to allow the user complete versatility in the processing of film samples.

Another reason for this manual control is for the draining and cleaning of tanks when finished with the device. To drain a tank, the procedure is as follows:

a.) Locate the manual drain valve. It is the extra length of tubing that extends out from the top row of valves. Open the valve and place the free end of the tubing into a suitable container. See figure 21 for a schematic diagram of this system.

b.) Depress one of the tank outlet buttons on the front panel. The valve should open with a loud snap. No more than one tank out button should be on at a time. If the manual drain valve is open, do not open any of the tank inlet valves, otherwise the tank will take forever to drain. Now that the bottom of a tank is open, depress the PUMP ON switch. Remember that the pump will only go on if the chamber door is sealed. Also, always keep a piece of film in the chamber when draining tanks, as this makes a better seal in the chamber and it is less likely to leak.

c.) The tank should now be draining through the drain valve. Listen carfully for a sudden increase in pump speed. This is the best indication of when the tank is empty. Quickly turn off the pump, then the tank out valve. Repeat for any other tanks that need draining.

Important Note: NEVER NEVER!! try to operate the pump without having at least one outlet valve open and one inlet valve open. The drain valve can take the place of a inlet valve, however. The point is that the pump must always have a souce from which to draw fluid and someplace to put the fluid. The pump can be damaged if made to draw from sealed tanks or empty tanks. Also, hoses may burst if the pump is not given an outlet destination. Therefore, ALWAYS make sure that the proper valves are open before turning on the pump. It is very easy to make this mistake so, BE CAREFUL!!!

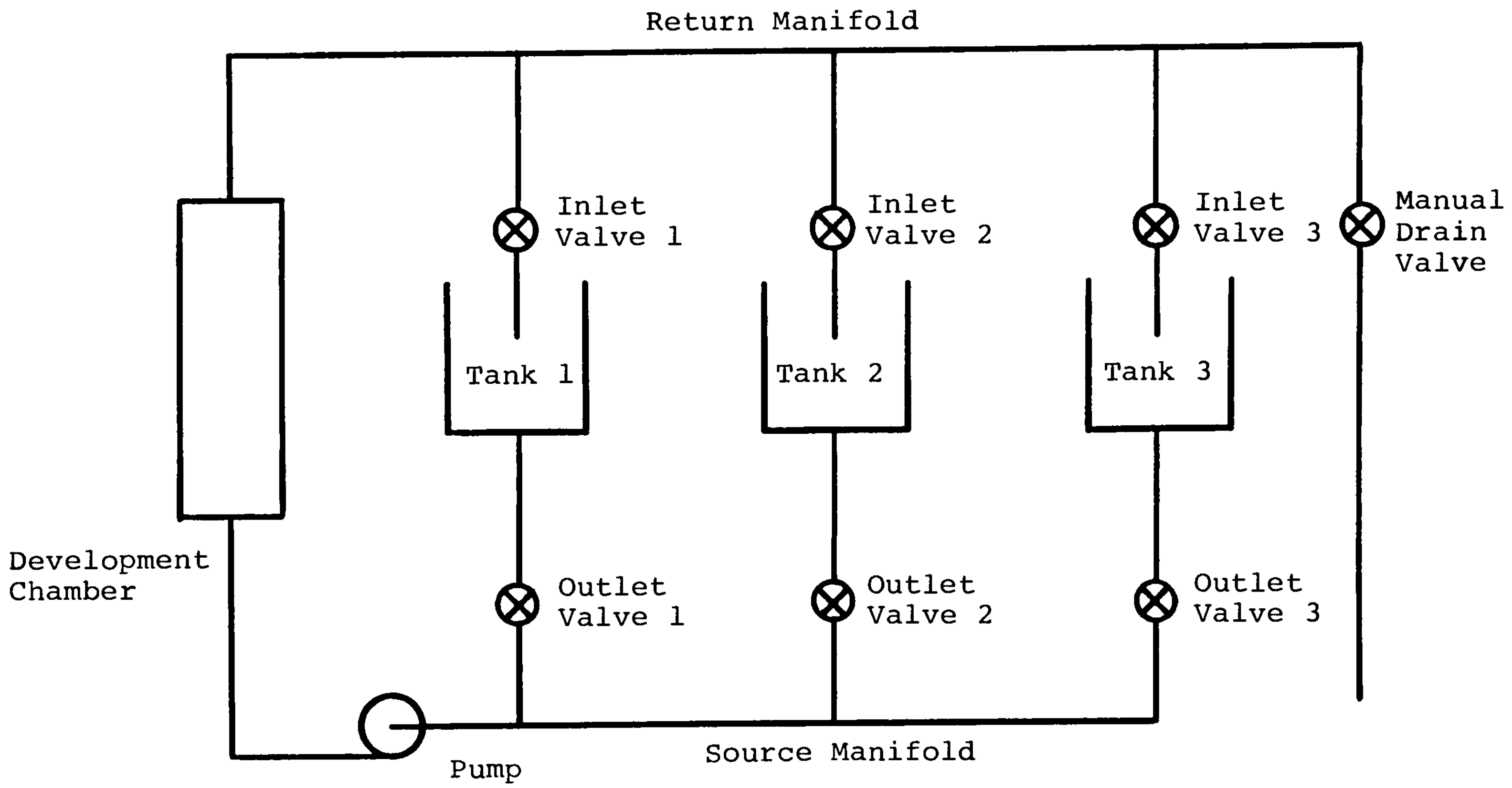

Figure 21: Fluid Transport System Hydraulic Schematic.

Tank Cleaning:

The best method for cleaning the tanks is also the eaisest. Place the device into manual mode. Fill all three tanks with clean, lukewarm water. Set the pump speed to about "5". Load a clean film sample in the development chamber. Open tank 1 inlet valve and outlet valve. Start the pump and run it for about 30 seconds. Now open the drain valve and close tank 1 inlet valve. The tank should now drain. Repeat this for the remaining two tanks. Remember that when the pump speed begins to increase, the tank is empty and the pump must be turned off immediately.

F.) Prompt Descriptions and Error Messages:

This section gives a brief description of every prompt the user will encounter when operating the In-process IR densitometer. The prompts are listed in their order of appearance to help guide the user through all steps of device usage.

Prompt	User Action
"EMITTER CAL?"	Device wishes to know if user would like to perform a hardware emitter output calibration. See calibration section for details. To perform the calibration, enter any number, then press "E". System will respond with "EMITTER 1,2,3..." for each "E" depression. Eleven depressions return the user to orignal prompt. To exit, or skip calibration, enter zero and press "E".
"ENTER D-MAX"	Enter the density value for the sample used as calibration standard. See calibration section for details. Density values are entered to the nearest hundredth with the decimal point implied. Example; 1.20 is entered as 120. Press "E" after entering correct value.
"READ D-MAX"	This is the prompt for the actual reading of the calibration standard. Place film stock sample and calibration strip into chamber and seal. Press "E" to take reading.
"READ ZERO"	Remove calibration strip from chamber, but leave film stock sample. Seal chamber door and press "E" to take zero reading. See calibration section for complete explantion of calibration routine.
"ENTER MONTH"	System is prompting for information so it can print a date header. Enter two digit month

	code followed by "E" depression.
"ENTER DAY"	Enter two digit day code, followed by "E".
"ENTER YEAR"	Enter two digit year code, followed by "E". system will print date header in the format: xx/yy/zz.
"MANUAL MODE?"	System is asking user if manual or automatic control of the Fluid Transport System (FTS) is desired. Any number entered followed by the "E" key will enable front panel buttons and put FTS under manual (user) control. A zero followed by "E" will place FTS under automatic (computer) control. See FTS description for details. If manual mode is selected, system will print: ** MANUAL MODE SELECTED **.
"PROCESS 1=?"	Enter 1st process length in minutes. Legal range is zero to 127 minutes. Process length can only be entered in increments of one minute. See data entry section for details. After depressing "E" key, system will print: Process 1 = xyz minutes.

Note: An entered process length of zero minutes will jump user to "PROCESS 2=?" prompt. However, if manual mode has been selected, system will display "BEGIN" query instead and assume no scan data is to be taken.

"INTERVAL 1=?"	Enter interval length in minutes; then press the "E" key. For the programming of scan acquisitions, the user must break up the entered process length into indivdual intervals. For each interval, the user must then enter a scan acquisition rate (see below). The sum of all the entered intervals cannot be greater than the total process length. If the sum is greater, an error prompt is issued.

See error prompts for details.

"RATE 1=?" For the just-entered interval, a scan acquisition rate must now be entered. Legal rate entries are 1 scan/minute to 60 scans/minute (these translate to 60 seconds per scan to 1 second per scan).The system has the ability to store 187 complete scans. A running sum is kept internally as the user programs intervals and rates. The number of scans any combination generates is simply the rate times interval length.

If an entered rate value, in conjunction with the just entered interval, generates a scan sum greater than 187, the system prompts "RATE TOO BIG". If the scan sum exactly equals 187, the system prompts: "OUT OF SCANS" and prints out as follows:

Interval 01 = ab minutes

Rate 01 = xy scans/minute

"INTERVAL 2=?" Interval/rate combinations may be entered until:

1.) The sum of interval lengths equals process length.

2.) Scan sum equals 187. Note that even though this is stored internally, it is not available for user display, and it is therefore the users resposibilty to keep track of the scan sum independently of the machine.

3.) Ten interval/rate pairs have been entered.

Note: Entering an interval length of 00 minutes will jump the user to the next process. In the case of manual mode, only one process is allowed.

"PROCESS 2=?"

"PROCESS 3=?" Same methodology applies for Process 2 and 3. As an example, if all scans are programmed in Process 1 and the "OUT OF SCANS" prompt is obtained, the remaining processes can still be run, however no scan acquisition data can be programmed.

"BEGIN" At this point, system is ready to begin processing. User should now check to see that tanks are filled, chamber door is sealed, etc. Processing will begin when enter key is depressed. If manual mode has been selected, it is up to the user to operate the manual FTS controls. Scan acquisition will still be under computer control, however. If manual mode has not been selected, the FTS will be under complete computer control also.

Note: When processing is started, all displays will go blank (except the digital thermometer). The user can do nothing until processing is complete. If the processing must be interrupted, the main power switch is the only way to stop the device.

"PROCESS #=?" When processing is complete, system returns with this prompt. User is now to enter process number from which it is desired to view scan data. Legal entries are 1,2, or 3 only, followed by "E". If a process number is entered for which no scan acquisition data has been programmed, the error prompt "NO DATA" is displayed.

"TIME WANTED" First set of double zeros are the number of minutes into selected process user wishes to view data. Legal entry range is 00 to 99 minutes, followed by the "E" key.

"TIME WANTED" Second set of zeros are the number of seconds to be added to the number of minutes already entered to form total time into process user wishes to view scan data. Legal entry range is 00s to 99 seconds, followed by "E".

Note: Time entries of 00 min 00 sec are not allowed and will return user to "PROCESS #=?" prompt.

"TIME ELAPSED" The times at which scans are made depends on how the scan acquisition data was programmed. Therefore it is possible for the user to enter a time at which no scan was made. The system will locate the closest scan made to the elapsed time wanted and display this actual scan time along with the scan data on the density display.

Data View Mode :

Once the first set of scan data is displayed, the special function keys become operative. Their functions are outlined below:

UP: Depressing this key will advance user to next acquired scan. Density display will show this new information and prompt display will be updated to show change in elapsed time. If already showing last scan in process, system will display: "NO MORE DATA".

DWN: This key will cause system to display scan acquired prior to present scan already on display. Note that time steps between scans are determined by scan rate information programmed earlier by the user. If very first scan in process is already being displayed, pressing "DWN" will cause system to display: "NO MORE DATA".

PRT: This key will cause the line printer to generate a copy of the scan data presently being displayed. The process number along with the elasped time are also printed as the header. This key has absolutly no effect on the display contents.

NXT: Depressing this key will simply return the user to the prompt: "PROCESS #=?". In this fashion, desired scans can be arrived at directly, rather than inched up to with the UP and DWN keys.

"E"-"E" Two "enter" key-strokes in sucession will return the user to "MANUAL MODE" query. This is to be done only when the user has completed the inspection of process results and wishes to make a new process run. Any number entered followed by an "E" will then enable the FTS manual control. This is to allow the user to change or alter the contents of the process tanks if so desired. A zero followed by the "E" key will jump the user back to the "ENTER MONTH" prompt. An entire new process run can now be programmed. All calibration values obtained earlier are retained.

Note: Once the user has entered two "E" key strokes, there is no way to return to the data view mode except to run a complete new process. Also, the double "E" stroke will only work when the message: "TIME ELAPSED" is on the prompt display.

Error Messages :

The following error prompts are returned by the system when the user makes an illegal or invalid keyboard entry. Error prompts will appear after an "E" depression and remain on the display for approximately five seconds. After this time, the system will reprompt the user for the correct entry. For critical errors, the re-prompt will be flashing on and off to alert the user that some careful thought is required.

Error prompt:	Meaning:
"PROCESS FULL"	Not really an error, but just informing the user that the sum of entered intervals now equals entered process length, and no more interval entries will be allowed.
"RATE TOO BIG"	Entered rate in conjunction with just entered interval will generate more scans than system is capable of storing (187). Solution: re-enter smaller rate.
"OUT OF SCANS"	A reminder to the user that all scans have been used up. Further interval/rate entries will not be allowed.
"NO DATA"	Response to user request for data from a process where none has been acquired.
"NO MORE DATA"	Response generated as user views a block of scan data and comes to the top or bottom of that data block.

Note: Certain types of invalid entries will generate no error message. What will happen, however, is that the number field of the prompt display will be re-set to all zeros, and the prompt will begin to flash. In this way, the user cannot proceed in system programming until a legal entry is made.

G.) Printer Maintenance:

There are only two types of service operations the IR densitometer user may attempt on the 40-column line printer. They are to change the ribbon cassette and to install a new roll of paper. For other problems, it is recommended that the printer manufacturer be consulted (NCR corporation).

Important note: Always disconnect the A.C. power cord before attempting to service the printer. A.C. line voltage is present within the control cabinet and a severe electrical shock could result from the inadvertent touching of one of these connections.

To install a new ribbon cassette:

1. Remove the old ribbon cassette from the printer. This is done by gently squeezing the two plastic locking tabs at the center edges of the cassette together and lifting the cassette off the printer.

2. Before installing the new cassette, locate the small white ribbon advace knob on the underside of the cassette. Slowly turn the knob in the direction indicated by the arrow until any slack in the ribbon is removed. To replace the cassette on the printer, again squeeze the locking tabs together and set the cassette back onto it's support tongs.

To install a new roll of paper:

1. Remove the ribbon cassette from the printer as described above.

2. Lift out the two vent plugs located just behind the printer on top of the control cabinet.

3. Slide the entire top panel out the back of the cabinet. Pull the panel out squarely as to prevent it from jamming. Lift slightly as the front end passes over the printer mechanism.

4. Step behind the device and view the paper feed spool located just behind the printer. Remove the wood spool from it's supports by lifting straight up on it at both ends.

5. Slide off the two plastic spacers and discard the cardboard core from the old roll. Insert the wool spool into a fresh roll of paper. The curl of the paper should be facing you. The long plastic spacer goes on the left and the short one on the right. Replace the entire assembly by guiding the slots in the spool into the U-shaped support holes.

6. <u>Important!!</u> Check now to see that the paper roll rotates freely on the spool and that it does not bind. If the roll is binding, it is because the wood spool was not replaced squarely in it's supports. Remove and replace if necessary.

7. While still standing behind the device, locate the feed roller release lever. This is a white plastic lever on the right hand side of the printer. Gently pull this lever towards you and note how the platen lifts away from the feed roller. While holding the platen open, feed the end of the paper under the metal roller opposite the rubber feed roller. Guide the paper out the top of the printer until the paper is feeding squarely

off the supply roll. Release the lever and tear off the excess paper you just pulled through.

8. Replace the top panel, again lifting the front edge slightly as it passes over the printer. Replace the two vent plugs. Before replacing the ribbon cassette, remove any slack by turning the white knob that is under the cassette in the direction indicated.

9. Reconnect the A.C. power.

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Appendix 1 : Input/Output Port and Peripheral Device Addressing

1.) Line Printer Data and Control Lines:

The 40-column line printer is considered to be I/O mapped I/O. That is to say, all operations with the printer are made through three I/O ports. Port addresses and bit designations are listed below. Data is clocked into the printer by the printer clock input line and the clock signal itself is derived from the Timer Out pin located on the expansion 8155 (chip A17). The Printer Reset input is derived from the buffered 8085A Reset Out signal. See the NCR users manual and the SDK-85 users manual for more complete details.

PORT 23H : Define as Input.

Bit C5 : Not Used
Bit C4 : Not Used
Bit C3 : Not Used
Bit C2 : Motor Jam
Bit C1 : Printer Busy
Bit C0 : Not Used

PORT 22H : Define as Output.

Bit B7 : Not Used
Bit B6 : Not Used
Bit B5 : Not Used
Bit B4 : Not Used
Bit B3 : Not Used
Bit B2 : Not Used
Bit B1 : Not used
Bit B0 : Printer Write

PORT 21H : Define as Output.

Bit A7 : Data 7
Bit A6 : Data 6
Bit A5 : Data 5
Bit A4 : Data 4
Bit A3 : Data 3
Bit A2 : Data 2
Bit A1 : Data 1
Bit A0 : Data 0

2.) A/D Converter Control and Data Lines:

All the Input/Output ports listed below have been optically isolated from the peripherals they communicate with. The devices used are Hewlett-Packard 2731 opto-isolators. For more details, consult the system schematics in the appendix. The purpose of the isolation is prevent noise crossover between the digital and analog systems.

PORT 2BH : Define as Output.

Bit C5 : Not Used
Bit C4 : Not Used
Bit C3 : Not Used
Bit C2 : Not Used
Bit C1 : Not Used
Bit C0 : Start Conversion

PORT 2AH : Define as Input.

Bit B7 : Conversion Status
Bit B6 : Not Used
Bit B5 : Not Used
Bit B4 : Not Used
Bit B3 : Not Used
Bit B2 : Not Used
Bit B1 : Conversion Bit 1 (MSB)
Bit B0 : Conversion Bit 2

PORT 29H : Define as Input.

Bit A7 : Conversion Bit 3
Bit A6 : Conversion Bit 4
Bit A5 : Conversion Bit 5
Bit A4 : Conversion Bit 6
Bit A3 : Conversion Bit 7
Bit A2 : Conversion Bit 8
Bit A1 : Conversion Bit 9
Bit A0 : Conversion Bit 10 (LSB)

3.) FTS Control Output Bit Assignments:

The following bit assignments are all defined as outputs. The multiplexer address lines are optically isolated from the analog system to prevent noise cross-talk. All output bits are buffered by 74LS240s. These bits are wired in parallel with the buttons on the control panel (manual).

PORT 00H

Bit A7 : Not Used
Bit A6 : Not Used
Bit A5 : Not Used
Bit A4 : Not Used
Bit A3 : Multiplxer Address Line A3
Bit A2 : Multiplxer Address line A2
Bit A1 : Multiplxer Address Line A1
Bit A0 : Multiplxer Address Line A0

PORT 08H

Bit A7 : Not Used
Bit A6 : Not Used
Bit A5 : Not Used
Bit A4 : Not Used
Bit A3 : Not Used
Bit A2 : Not Used
Bit A1 : FTS Automatic Enable (0 = "enable")
Bit A0 : FTS Manual Enable (0 = "enable")

PORT 09H

Bit B7 : Not Used
Bit B6 : Pump (1 = "on", 0 = "off")
Bit B5 : Valve 3 Out
Bit B4 : Valve 3 In
Bit B3 : Valve 2 Out
Bit B2 : Valve 2 In
Bit B1 : Valve 1 Out
Bit B0 : Valve 1 In

4.) 33-Digit Density Display/Keyboard System:

The 33-digit density display system is controlled by the expansion 8279 keyboard/display controller. This controller has an internal 16 byte/32 digit display RAM that is written to and read from by the 8085A CPU. For a more complete understanding on how the 8279 works, refer to the Intel MCS-85 User's Manual #9800366E.

Display Section:

The 8279 can be considered as memory mapped I/O. It is communicated with via the CPU as if it were a simple memory location. The two addresses of concern are:

Command Address	:	B801H
Data Address	:	B800H

Each byte in the display RAM is configured as : BBBBAAAA, where the four hi-order bits make up the B section and the four lo-order bits make up the A section. The hardware is set up to display each section as a BCD digit. Therefore, sixteen bytes of RAM with two nibbles each give a total of thirty-two digits. The physical display addresses are shown in the following list. The top left most digit is hard-wired to always read zero.

0.	A0	A1
A2	A3	A4
A5	A6	A7
A8	A9	AA
AB	AC	AD
AE	AF	B0
B1	B2	B3
B4	B5	B6
B7	B8	B9
BA	BB	BC
BD	BE	BF

Digit addresses in relation to their physical position. (top view).

Keyboard Section:

The 8279 keyboard section is used in the encoded scan mode with 2-key lock out. When reading the FIFO, keystroke addresses are mapped as shown below:

CFH	CBH	C7H	C3H	
CEH	CAH	C6H	C2H	Keystroke addresses in
CDH	C9H	C5H	C1H	relation to actual key
CCH	C8H	C4H	C0H	pad location (top view).

5.) Twelve Character Alphanumeric display:

The twelve character 5x7 dot matrix alphanumeric display is controlled by the MTX-A1 display controller. The MTX-A1 is also set up as memory mapped I/O and therefore is treated as a single memory location. All commands and display data are written to what is known as the control address.

Control Address : BF00H

The MTX-A1 also contains a 32-character RAM, and is very similar in operation to the 8279. For complete details of operation, see the MTX-A1 User's Manual.

The relationship between character address and physical location is shown below:

B A 9 8 7 6 5 4 3 2 1 0

The display is written to from right to left and any excess characters roll off the left end and are lost.

6.) Five Digit Control Display:

These five display are simply wired in parallel with the displays mounted on the SDK-85. There is a small eight position

DIP switch located on the SDK-85 board that is used to switch between the two display systems. These displays are controlled by the Basic 8279 Display Controller. See Chapter Five of the SDK-85 System Design Kit User's Manual #9800451B for a very complete description on how these displays are used.

Data Address : 1800H

Command Address : 1900H

7.) I/O Port and Memory Map:

I/O Map:

Port Address	Port Name	Chip
00H	Basic ROM Port A	A14
01H	Basic ROM Port B	A14
02H	Basic ROM DDRA	A14
03H	Basic ROM DDRB	A14
08H	Expansion ROM Port A	A15
09H	Expansion ROM Port B	A15
0AH	Expansion ROM DDRA	A15
0BH	Expansion ROM DDRB	A15
20H	Basic RAM CSR	A16
21H	Basic RAM Port A	A16
22H	Basic RAM Port B	A16
23H	Basic RAM Port C	A16
24H	Basic Lo-Order Timer Control	A16
25H	Basic Hi-Order Timer Control	A16
28H	Expansion RAM CSR	A17
29H	Expansion RAM Port A	A17
2AH	Expansion RAM Port B	A17
2BH	Expansion RAM Port C	A17
2CH	Expansion Lo-Order Timer Control	A17
2DH	Expansion Hi-Order Timer Control	A17

Memory Map:

Active Address Range	Selected Device
0000-07FF	8755 Basic UVEPROM
0800-0FFF	8755 Expansion UVEPROM
1000-17FF	Not Used
1800-1FFF	8279 Basic Controller
2000-27FF	8155 Basic RAM
2800-2FFF	8155 Expansion RAM
3000-7FFF	Not Used
8000-87FF	2142 RAMs (4)
8800-8FFF	2114 RAMs (4)
9000-97FF	Not Used
9800-9FFF	2716 UVEPROM
A000-AFFF	2732 UVEPROM
B000-B7FF	2716 UVEPROM
B800-BBFF	8279 Expansion Controller
BC00-BFFF	MTX-A1 Display Controller
C000-FFFF	Not Used

See SDK-85 User's Manual for more complete details on memory allocation.

Appendix 2 : Operating System Program Listings :

The most difficult portion of this thesis involved the development of the operating system control software. This appendix contains a short description of what each program does, followed by the complete listing of the assembled programs. The code is Intel 8080/8085 assembly language. All programs where developed on an Intel Intellec MDS-220 development system. All software calculations are performed by routines contained in the Intel Floating-Point Arithmetic Library (FPAL). The operations provided are addition, subtraction, multiplication, division value comparison, negation, clearing to zero, absolute value, conversion between decimal and binary floating-point numbers and conversion between floating-point and 32-bit signed integer formats. All operations are 32-bit single-precision (positive number range approximates 1.2×10^{-38} to 3.4×10^{38}). The 32-bit single-precision format is fully described in the 8080/8085 Floating-Point Arithmetic Library user's manual, available from Intel Corporation, Sanata Clara, California, order # 9800452-03.

Control of the IR densitometer is divided between seven different programs or modules. Each module is developed and debugged separately from one another. Once all programs are debugged, they are linked together to form one complete program. For this system, the linked programs require about 10K of program memory to run.

These program listing are provided to allow qualified persons to change or up-grade the IR densitometer operating system when needed. If more information is required, please consult the numerous Intel manuals concerning this subject.

1. Module CALIB:

This module performs all the initializations required to operate the IR densitometer. For example, certain memory locations and registers will contain unknown variables upon first power up. This program then loads these locations with the proper contents. This program also contains the sub-routines that; scan the 11 emitter/detector pairs, manage the output of data onto the 33-digit display, and perform the data calibration functions.

2. Module START:

Module START is a warm start routine in that after a process has been run, certain parameters have to be re-initialized. START also contains all the routines that control the 40-column line printer.

3. Module DATAIN:

This module interacts directly with the densitometer user to program certain process information. All timing and rate information is entered through this program and is also checked for validity. The majority of message tables are stored within this module, along with all delay routines.

4. Module SUBPAK:

SUBPAK contains all the routines needed to operate the 16 pad keyboard. When the user depresses a key, subpak determines which key has been pressed and loads its address and value (if it is a numeric key) into a series of memory locations called KSTOR. From there, it is up to the calling program to determine what to do next.

5. Module GODEV:

This program starts by displaying "BEGIN" on the prompt display. From there it simply controls the timing of the Fluid Transport System, and the timing of scan acquistion. GODEV also contains a memory allocation routine used to store density data as it is generated by the A/D converter. All timing functions are based on a 1 Hz clock input to RST 7.5.

6. Module DFIND:

This module is entered when processing is completed. The user enters a time at which density data was acquired, and the routine will calculate the memory address at which that data is stored. A routine to convert minutes to seconds is also contained here.

7. Module UPORDN:

Control of the special function keys is defined here. This program functions very similar to DFIND in that memory addresses are calculated depending on what density data is desired. Exit from this program will return the user to START where a new process run can be made.

```
LOC  OBJ         SOURCE STATEMENT

            ;Date 7/26/81 revision 5, 8/11/81 revision 6, 8/29/81 revision 7.
            ;
            ;  The In-Process IR Densitometer is controlled by seven program
            ;  modules.  The module names are: CALIB, START, DATAIN, SUBPAK,
            ;  CODEV, DFIND, and UPORDN.
            ;
            ;       ***  All programs by Steven p. Cox  ***
            ;
            ;*****************************************************************
            ;
            ;       Main start routine for In-process IR Densitometer.
            ;       This program prompts the user through all steps of the
            ;       start up calibration routine. After calibration, program
            ;       control is given to START and then to DATAIN routine.
            ;
            ;*****************************************************************
            ;
                    NAME    CALIB
            ;
                    PUBLIC  COMM1,DATA1,COMM2,DATA2,ALPHA,PA1,PB1,PC1,RAMPT
                    PUBLIC  RPA2,RPB2,RPA1,POS2,POS1,RPOS1,CLEARA,CLEARB,SCAN,DSHOW
                    PUBLIC  DRAM,NXDRAM,TMPNUM,TDSTOR
            ;
                    EXTRN   KDSPY2,KSTOR1,KSTOR2,FSET,FERHND,FCLR,FLOAD,FQFB2D
                    EXTRN   KDSPY3,SUM3,FLTDS,FSTOR,FDIV,FMUL,FNEG,FSUB,FADD,START
                    EXTRN   DELAY,DWRITE,SUM2,DEB
            ;
            ;.................................................................
            ;       Below are the variable names used in naming I/O port, display
            ;       command and data addresses.
            ;.................................................................
            ;
1900                COMM1   EQU     1900H   ; Basic 8279 command address.
1800                DATA1   EQU     1800H   ; Basic 8279 data address.
B801                COMM2   EQU    0B801H   ; Expansion 8279 command address.
B800                DATA2   EQU    0B800H   ; Expansion 8279 data address.
0020                CS1     EQU       20H   ; Basic RAM C/S REGISTER.
0021                PA1     EQU       21H   ; BASIC RAM PORT A.
0022                PB1     EQU       22H   ; BASIC RAM PORT B.
0023                PC1     EQU       23H   ; BASIC RAM PORT C.
0024                T1LOB   EQU       24H   ; LO-ORDER BYTE OF BASIC TIMER.
0025                T1HOB   EQU       25H   ; HI-ORDER BYTE OF BASIC TIMER.
0028                CS2     EQU       28H   ; EXPANSION RAM C/S REGISTER.
0029                PA2     EQU       29H   ; EXPANSION PORT A
002A                PB2     EQU       2AH   ; EXPANSION PORT B.
002B                PC2     EQU       2BH   ; EXPANSION PORT C.
002C                T2LOB   EQU       2CH   ; LO-ORDER BYTE OF EXPANSION TIMER.
002D                T2HOB   EQU       2DH   ; HI-ORDER BYTE OF EXPANSION TIMER.
BF00                ALPHA   EQU    0BF00H   ; MTX-A1 CONTROL ADDRESS.
0000                RPA1    EQU       00H   ; BASIC ROM PORT A.
0001                RPB1    EQU       01H   ; BASIC ROM PORT B.
0002                RDDA1   EQU       02H   ; BASIC ROM DDR FOR PORT A.
0003                RDDB1   EQU       03H   ; BASIC ROM DDR FOR PORT B.
```

```
LOC  OBJ          LINE         SOURCE STATEMENT

0008                54         RPA2    EQU     08H    ; EXPANSION ROM PORT A.
0009                55         RPB2    EQU     09H    ; EXPANSION ROM PORT B.
000A                56         RDDA2   EQU     0AH    ; EXPANSION ROM DDR FOR PORT A.
000B                57         RDDB2   EQU     0BH    ; EXPANSION ROM DDR FOR PORT B.
0000                58         DRAM    EQU     0000H  ; START ADDRESS OF DENSITY RAM.
0001                59         MDMAXT  EQU     0001H  ; START OF MEASURED D-MAX DENSITY RAM.
0017                60         MDOT    EQU     0017H  ; START OF MD0 RAM.
                    61 ;
                    62         CSEG
                    63 ;
0000 31FF20         64 CALIB:  LXI     SP,     20FFH  ; STACK AT END OF EXPANSION RAM.
0003 210019         65         LXI     H,      COMM1  ; LOAD DISPLAY COMMAND ADDRESS.
0006 3600           66         MVI     M,      00H    ; 8 DIGIT, LEFT ENTRY, 2 KEY LOCK-OUT.
0008 CD0000    E    67         CALL    DELAY
000B 36DC           68         MVI     M,      0DCH   ; CLEAR CONTROL DISPLAY RAM TO ZEROS.
000D 2101B0         69         LXI     H,      COMM2
0010 36A3           70         MVI     M,      0A3H   ; TURN DENSITY DISPLAY OFF.
0012 CD0000    E    71         CALL    DELAY
0015 3E40           72         MVI     A,      40H
0017 D32D           73         OUT     T2HOB                 ; PROGRAM HI-ORDER BYTE OF EXPANSION TIMER.
0019 3E06           74         MVI     A,      06H
001B D32C           75         OUT     T2LOB                 ; PROGRAM LO-ORDER BYTE OF EXPANSION TIMER.
001D 3ECC           76         MVI     A,      0CCH   ; PC2=OUT PB2=IN PA2=IN
001F D328           77         OUT     CS2                   ; SET-UP EXPANSION I/O & START TIMER.
0021 3E00           78         MVI     A,      00H    ; SET CONVERT LINE TO LO.
0023 D32B           79         OUT     PC2
0025 3E03           80         MVI     A,      03H    ; SET UP I/O FOR BASIC RAM.
0027 D320           81         OUT     CS1                   ; PRINTER CONTROL LINES.
0029 3EFF           82         MVI     A,      0FFH
002B D30A           83         OUT     RDDA2                 ; SET ALL BIT ON EXPAN. ROM PORT A TO OUTS.
002D D30B           84         OUT     RDDB2                 ; SAME FOR EXPAN. ROM PORT B.
002F 3EFD           85         MVI     A,      0FDH
0031 D308           86         OUT     RPA2                  ; ENABLE FTS CONTROL TO AUTO MODE.
0033 AF             87         XRA     A
0034 D309           88         OUT     RPB2                  ; TURN OFF ALL VALVES AND PUMP.
0036 3E0F           89         MVI     A,      0FH    ; SET BASIC ROM PORT A TO OUTPUT.
0038 D302           90         OUT     RDDA1                 ; THESE ARE MUX ADDRESS LINES.
003A 3E00           91         MVI     A,      00H    ; PRESET MUX ADDRESS LINES TO 0000B.
003C D300           92         OUT     RPA1
003E 2100BF         93         LXI     H,      ALPHA  ; LOAD 12 CHARACTER CONTROL ADDRESS.
0041 36E1           94         MVI     M,      0E1H   ; LOAD ALL BLANKS TO DISPLAY RAM.
0043 CD0000    E    95         CALL    DELAY
0046 36C3           96         MVI     M,      0C3H
0048 3E93           97         MVI     A,      93H    ; INITIALIZE PARAMETERS USED IN KDSPY2.
004A 326500    D    98         STA     POS2
004D 3E04           99         MVI     A,      04H
004F 326400    D   100         STA     POS1
0052 3E64          101         MVI     A,      64H
0054 326600    D   102         STA     RPOS1
0057 3EDF          103         MVI     A,      0DFH
0059 320000    D   104         STA     CLEARA                ; INITALIZE ENTRY CLEAR TO KDSPY2.
005C 320100    D   105         STA     CLEARB                ; INITIALIZE EXIT CLEAR FROM KDSPY2.
005F CD0000    E   106         CALL    DELAY
0062 219903    C   107 ECAL:   LXI     H,      EMITM  ; PROMPT " EMITTER CAL? ".
```

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 LOC  OBJ          LINE        SOURCE STATEMENT

0065 060D           108         MVI     B,      0DH
0067 CD0000    E    109         CALL    DWRITE
006A CD0000    E    110         CALL    KDSPY2          ; ENTER WILL BYPASS ROUTINE.
006D 3A0000    E    111         LDA     SUM2
0070 FE00           112         CPI     00H
0072 CAAA00    C    113         JZ      INIT
0075 3E01           114         MVI     A,      01H     ; ANYTHING ELSE WILL TURN ON EMITTER 1.
0077 4F             115         MOV     C,      A       ; C REG IS MUX ADDRESS COUNTER.
0078 320000    E    116 SETIT:  STA     DEB             ; DEB CONTAINS DISPLAY NUMBER.
007B 79             117         MOV     A,      C
007C D300           118         OUT     BPA1            ; TURN ON EMITTER ADDRESSED BY C.
007E C5             119         PUSH    B
007F 219003    C    120         LXI     H,      EMIT    ; DISPLAY " EMITTER (DEB) ".
0082 060A           121         MVI     B,      0AH
0084 CD0000    E    122         CALL    DWRITE
0087 3A0000    E    123         LDA     DEB
008A C630           124         ADI     30H             ; CONVERT DEB TO ASCII.
008C 3200BF         125         STA     ALPHA           ; SEND TO ALPHA DISPLAY.
008F CD0000    E    126         CALL    KDSPY2          ; WAIT.
0092 C1             127         POP     B
0093 3A0000    E    128         LDA     DEB
0096 3C             129         INR     A               ; INCREMENT NUMBER COUNTER
0097 0C             130         INR     C               ; INCREMENT ADDRESS COUNTER.
0098 FED3           131         CPI     0D3H            ; COMPARE TO " C ".
009A CA6200    C    132         JZ      ECAL
009D FE0A           133         CPI     0AH
009F CAA500    C    134         JZ      FIX
00A2 C37800    C    135         JMP     SETIT
00A5 3ED1           136 FIX:    MVI     A,      0D1H
00A7 C37800    C    137         JMP     SETIT
                    138 ;
                    139 ;       INITIALIZE FPAL:
                    140 ;
00AA 3E00           141 INIT:   MVI     A,      00H     ; RESET MUX LINES TO 0000B.
00AC D300           142         OUT     BPA1
00AE 010800    D    143         LXI     B,      FPR
00B1 C5             144         PUSH    B
00B2 010000         145         LXI     B,      00H
00B5 CD0000    E    146         CALL    FSET
                    147 ;
00B8 21A503    C    148 GDMAX:  LXI     H,      DMAX    ; PROMPT " ENTER D-MAX "
00BB 060E           149         MVI     B,      0EH
00BD CD0000    E    150         CALL    DWRITE          ; WRITE MESSAGE.
00C0 CD0000    E    151         CALL    KDSPY3          ; ENTER D-MAX CALIBRATION VALUE(ADMAX).
00C3 3A0000    E    152         LDA     SUM3            ; SUM3 CONTAINS ENTRY AS XYZ, IMPLIED X.YZ
00C6 321A00    D    153         STA     ADMAX           ; STORE ADMAX AS 32-BIT INTEGER.
00C9 AF             154         XRA     A
00CA 321B00    D    155         STA     ADMAX+1
00CD 321C00    D    156         STA     ADMAX+2
00D0 321D00    D    157         STA     ADMAX+3
00D3 010800    D    158         LXI     B,      FPR     ; NOW CONVERT TO 32-BIT FLOATER.
00D6 111A00    D    159         LXI     D,      ADMAX
00D9 CD0000    E    160         CALL    FLTDS
00DC CD0000    E    161         CALL    FSTOR           ; STORE ADMAX AS FLOATER.
```

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LOC  OBJ          LINE        SOURCE STATEMENT

00DF 21BA03   C    162 RDMAX:  LXI    H,      RDDEN   ; PROMPT " READ D-MAX ".
00E2 060C          163         MVI    B,      0CR
00E4 CD0000   E    164         CALL   DWRITE
00E7 CD0000   E    165         CALL   KDSPY2          ; CONTINUE ON RECEIPT OF ENTER KEY.
00EA 210080        166         LXI    H,      DRAM    ; INITALIZE NIDRAM.
00ED 220200   D    167         SHLD   NIDRAM
00F0 212600   D    168         LXI    H,      SLOPE   ; INITALIZE SLOPE POINTER.
00F3 225200   D    169         SHLD   SLOPEP
00F6 CD8D01   C    170         CALL   SCAN            ; 1ST 22 BYTES OF NIDRAM NOW CONTAIN MDMAX.
00F9 21B003   C    171 GZERO:  LXI    H,      DZERO   ; PROMPT " READ ZERO ".
00FC 060B          172         MVI    B,      0BH
00FE CD0000   E    173         CALL   DWRITE
0101 CD0000   E    174         CALL   KDSPY2          ; CONTINUE ON RECEIPT ON ENTER KEY.
0104 CD8D01   C    175         CALL   SCAN            ; 2ND 22 BYTES OF NIDRAM CONTAIN MD0.
0107 211780        176 CALSLP: LXI    H,      MD0T    ; INITALIZE START ADDRESS OF 22 BYTE MD0 RAM.
010A 222200   D    177         SHLD   MD0P
010D 210180        178         LXI    H,      MDMAXT  ; INITALIZE START ADDRESS OF MDRAM.
0110 222400   D    179         SHLD   MDMAXP
0113 7D            180 NXSLOP: MOV    A,      L       ; AT THIS POINT L CONTAINS LOB OF MDMAXP.
0114 FE17          181         CPI    17H
0116 CA0A01   C    182         JZ     FINCAL          ; IF EQUAL, THEN HAVE CALCULATED 11 SLOPES.
0119 2A2200   D    183         LHLD   MD0P
011C 7E            184         MOV    A,      M       ; PLACE LOB OF MD0 INTO A REG.
011D 321E00   D    185         STA    TFLOAT
0120 23            186         INX    H
0121 7E            187         MOV    A,      M       ; PLACE HOB (2 MSBITS) INTO A.
0122 321F00   D    188         STA    TFLOAT+1
0125 AF            189         XRA    A
0126 322000   D    190         STA    TFLOAT+2
0129 322100   D    191         STA    TFLOAT+3
012C 010800   D    192         LXI    B,      FPR
012F 111E00   D    193 COVRTS: LXI    D,      TFLOAT  ; CONVERT MD0 TO FLOATER, STORE IN TFLOAT.
0132 CD0000   E    194         CALL   FLTDS
0135 CD0000   E    195         CALL   FSTOR
0138 2A2400   D    196         LHLD   MDMAXP          ; LOAD LOB OF MDMAX INTO A REG.
013B 7E            197         MOV    A,      M
013C 320400   D    198         STA    TMPNUM
013F 23            199         INX    H
0140 7E            200         MOV    A,      M
0141 320500   D    201         STA    TMPNUM+1
0144 AF            202         XRA    A
0145 320600   D    203         STA    TMPNUM+2
0148 320700   D    204         STA    TMPNUM+3
014B 110400   D    205         LXI    D,      TMPNUM  ; B SHOULD STLL CONTAIN FPR.
014E CD0000   E    206         CALL   FLTDS           ; CONVERT MDMAX TO FLOATER, LEAVE IN FAC.
0151 111E00   D    207         LXI    D,      TFLOAT
0154 CD0000   E    208         CALL   FSUB            ; FAC = MDMAX - MD0 .
0157 CD0000   E    209         CALL   FSTOR           ; STORE RESULT IN TFLOAT.
015A 111A00   D    210         LXI    D,      ADMAX
015D CD0000   E    211         CALL   FLOAD           ; LOAD FAC WITH ENTERED ADMAX.
0160 111E00   D    212         LXI    D,      TFLOAT
0163 CD0000   E    213         CALL   FDIV            ; FAC = 1/M = ADMAX/( MDMAX - MD0 ).
0166 2A5200   D    214         LHLD   SLOPEP          ; LOAD HL WITH CONTENTS OF SLOPEP.
0169 EB            215         XCHG                   ; EXCHANGE WITH CONTENTS OF DE.
```

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 LOC  OBJ                SOURCE STATEMENT

 016A CD0000    E              CALL    FSTOR           ; STORE 4-BYTE SLOPE AT LOCATION POINTED
                                                       ; TO BY SLOPE POINTER ( SLOPEP ).
 016D 2A5200    D        INKS: LHLD    SLOPEP          ; INCREMENT SLOPE COUNTER BY 4.
 0170 23                       INX     H
 0171 23                       INX     H
 0172 23                       INX     H
 0173 23                       INX     H
 0174 225200    D              SHLD    SLOPEP
 0177 2A2200    D              LHLD    MDOP            ; INCREMENT MD0 POINTER BY 2.
 017A 23                       INX     H
 017B 23                       INX     H
 017C 222200    D              SHLD    MDOP
 017F 2A2400    D              LHLD    MDMAXP          ; INCREMENT MDMAX POINTER BY 2.
 0182 23                       INX     H
 0183 23                       INX     H
 0184 222400    D              SHLD    MDMAXP
 0187 C31301    C              JMP     NXSLOP          ; GO SEE IF MORE SLOPES TO BE CALCULATED.
                        ;
                        ;      AT THIS POINT ALL SLOPES ARE CALCULATED, READY TO MAKE DENSITY
                        ;
 018A C30000    E       FINCAL: JMP    START           ; GO TO ENTER DATE ROUTINE.
                        ;
                        ;      SUBROUTINES FOLLOW:
                        ;
                        ;*********************************************************************
                        ;
                        ;      ***  SCAN  ***
                        ;
                        ;  SCAN PERFORMS ONE COMPLETE SCAN OF THE IR DENSITOMETER BY
                        ;  READING EACH OF THE 11 IR DENSITOMETERS ONE AFTER ANOTHER.
                        ;  THE ROUTINE ASSUMES THAT NXDRAM, A 16-BIT ADDRESS WHERE DENSITY
                        ;  VALUES ARE TO BE STORED, HAS AREADY BEEN INITALIZED TO SOME VALUE.
                        ;
                        ;*********************************************************************
                        ;
 018D 2101B8            SCAN:  LXI     H,      COMM2            ; BLANK DENSITY DISPLAY.
 0190 36DF                     MVI     M,      0DFH
 0192 36A3                     MVI     M,      0A3H
 0194 CD0000    E              CALL    DELAY
 0197 CD0000    E              CALL    DELAY
 019A 3E01                      MVI     A,      01H     ; INITALIZE SCAN COUNTER,
 019C 325500    D              STA     SCNCNT
 019F FE0C              CKCCNT: CPI    0CH             ; HAVE 11 PASSES BEEN MADE?
 01A1 CAD701    C              JZ      RESET
 01A4 D380                     OUT     RPA1            ; PLACE SCNCNT CONTENTS ON MUX ADDRESS LINES.
 01A6 CD0000    E              CALL    DELAY           ; LEAVE THAT EMITTER/DETECTOR PAIR ON ~2MSEC
 01A9 3E01                     MVI     A,      01H     ; BRING CONVERT LINE HI
 01AB D32B                     OUT     PC2
 01AD 160F                     MVI     D,      0FH     ; EXTEND PULSE JUST A BIT.
 01AF 15                LP2:   DCR     D
 01B0 C2AF01    C              JNZ     LP2
 01B3 3E00                     MVI     A,      00H     ; BRING CONVERT LINE LOW, START CONVERSION.
 01B5 D32B                     OUT     PC2
 01B7 163F              BUSY:  MVI     D,      3FH     ; WAIT JUST OVER 25 MICROSECONDS.
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 LOC  OBJ          LINE        SOURCE STATEMENT

 01B9 15            270 LP1:    DCR     B
 01BA C2B901    C   271         JNZ     LP1
 01BD 2A0200    D   272         LHLD    NXDRAM          ; INCREMENT DRAM POINTER BY ONE.
 01C0 23            273         INX     H
 01C1 DB29          274         IN      PA2             ; BRING IN 1ST 8 BITS OF CONVERSION.
 01C3 77            275         MOV     M,      A
 01C4 23            276         INX     H               ; INCREMENT DRAM POINTER BY ONE MORE.
 01C5 DB2A          277         IN      PB2             ; BRING IN REMAINING 2 MSBITS.
 01C7 E603          278         ANI     03H             ; MASK OUT HI-ORDER 6 BITS.
 01C9 77            279         MOV     M,      A       ; STORE WHERE POINTED BY NXDRAM.
 01CA 220200    D   280         SHLD    NXDRAM          ; UPDATE NXDRAM.
 01CD 3A5500    D   281         LDA     SCNCNT
 01D0 3C            282         INR     A               ; INCREMENT SCAN COUNTER BY ONE.
 01D1 325500    D   283         STA     SCNCNT
 01D4 C39F01    C   284         JMP     CKGCNT
 01D7 3E00          285 RESET:  MVI     A,      00H     ; RESET MUX ADDRESS LINES TO ZERO.
 01D9 D300          286         OUT     RPA1
 01DB C9            287         RET
                    288 ;
                    289 ;**************************************************************************
                    290 ;
                    291 ;          ***  DSHOW  ***
                    292 ;
                    293 ;    DSHOW TAKES ONE 22-BYTE BLOCK OF DENSITY MEASURMENTS AND OPERATES ON
                    294 ;    IT WITH A LINEAR REGRESION CALIBRATION ROUTINE. THE RESULTS ARE THEN
                    295 ;    DISPLAYED ON THE 33-DIGIT DISPLAY SYSTEM. DSHOW MUST BE PASSED RAMPT,
                    296 ;    ( RAM POINTER ) TO TELL IT WHICH BLOCK OF DATA IS WANTED.
                    297 ;    THIS START ADDRESS IS FOUND FROM: DSTART = ( RAMPT X 22 ) + 1 + DRAM
                    298 ;
                    299 ;         SOME CONVENTIONS USED IN THIS SYSTEM ARE:
                    300 ;
                    301 ;         1.) DENSITY READINGS BEGIN AT THE TOP OF THE CHAMBER AND DECEND.
                    302 ;
                    303 ;         2.) THE LO-DENSITY PRODUCING END OF THE SENSI STRIP WILL BE
                    304 ;             PLACED AT THE TOP OF THE CHAMBER.
                    305 ;
                    306 ;         3.) VALUES WILL DISPLAYED AND PRINTED WITH THE LOWEST DENSITY
                    307 ;             READINGS ON TOP AND THE HIGHEST AT THE BOTTOM.
                    308 ;
                    309 ;         4.) THE LOWEST DENSITY READING OF ANY DATA BLOCK WILL MAP TO
                    310 ;             THE LOWEST OR START ADDRESS OF THAT DATA BLOCK.
                    311 ;
                    312 ;**************************************************************************
                    313 ;
 01DC 210000        314 DSHOW:  LXI     H,      0000H   ; ZERO HL REGISTER PAIR.
 01DF 3A5400    D   315         LDA     RAMPT
 01E2 FE00          316 NX:     CPI     00H
 01E4 CAEF01    C   317         JZ      OVER            ; CALCULATE ( RAMPT X 22 )
 01E7 111600        318         LXI     D,      0016H   ; LOAD DE WITH 22.
 01EA 19            319         DAD     D               ; HL = HL + DE .
 01EB 3D            320         DCR     A
 01EC C3E201    C   321         JMP     NX
 01EF EB            322 OVER:   XCHG                    ; STORE ( RAMPT X 22 ) IN DE.
 01F0 210080        323         LXI     H,      DRAM    ; LOAD HL WITH DENSITY START ADDRESSS.
```

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 LOC  OBJ          LINE        SOURCE STATEMENT

 01F3 23            324          INX    H              ; HL = DRAM + 1.
 01F4 19            325          DAD    D              ; HL = DRAM + 1 + ( RAMPT X 22 ) .
 01F5 225400    D   326          SHLD   DSTART
 01F8 211780        327          LXI    H,     MDOT    ; RE-INITIALIZE MDO POINTER FOR USE IN CORECT.
 01FB 222200    D   328          SHLD   MDOP
 01FE 212400    D   329          LXI    H,     SLOPE   ; RE-INITIALIZE SLOPE POINTER FOR USE IN SAME.
 0201 225200    D   330          SHLD   SLOPEP
 0204 2101B8        331          LXI    H,     COMM2   ; LOAD 8279 COMMAND ADDRESS.
 0207 3690          332          MVI    M,     90H     ; SET DISPLAY RAM TO 0000, AI.
 0209 CD0000    E   333 INHIBB: CALL   DELAY
 020C 36A5          334          MVI    M,     0A5H    ; BLANK AND WRITE INHIBIT B SEC OF DISPLAY.
 020E CD0000    E   335          CALL   DELAY
 0211 CD4C02    C   336          CALL   CORECT          ; FILL LO-DEN STEP, ACCOUNT FOR FIXED ZERO.
 0214 2100B8        337          LXI    H,     DATA2
 0217 3A5900    D   338          LDA    TDSTOR+1
 021A 77            339          MOV    M,     A
 021B CD0000    E   340          CALL   DELAY
 021E 3A5A00    D   341          LDA    TDSTOR+2
 0221 77            342          MOV    M,     A
 0222 CD0000    E   343          CALL   DELAY
 0225 CD7C03    C   344          CALL   DSEND
 0228 CD7C03    C   345          CALL   DSEND
 022B CD7C03    C   346          CALL   DSEND
 022E CD7C03    C   347          CALL   DSEND
 0231 CD4C02    C   348          CALL   CORECT
 0234 2100B8        349          LXI    H,     DATA2   ; ACCOUNT FOR SWITCH BETWEEN SEC A AND SEC B.
 0237 3A5800    D   350          LDA    TDSTOR
 023A 77            351          MOV    M,     A
 023B CD0000    E   352          CALL   DELAY
 023E 3A5900    D   353          LDA    TDSTOR+1
 0241 77            354          MOV    M,     A
 0242 CD0000    E   355          CALL   DELAY
 0245 2101B8        356          LXI    H,     COMM2
 0248 3690          357          MVI    M,     90H     ; SET RAM TO 0000.
 024A CD0000    E   358 INHIBA: CALL   DELAY
 024D 36A0          359          MVI    M,     0A0H    ; WRITE INHIBIT A SECTION OF RAM.
 024F CD0000    E   360          CALL   DELAY
 0252 2100B8        361          LXI    H,     DATA2
 0255 3A5A00    D   362          LDA    TDSTOR+2
 0258 77            363          MOV    M,     A
 0259 CD0000    E   364          CALL   DELAY
 025C CD7C03    C   365          CALL   DSEND
 025F CD7C03    C   366          CALL   DSEND
 0262 CD7C03    C   367          CALL   DSEND
 0265 CD7C03    C   368          CALL   DSEND
 0268 CD7C03    C   369          CALL   DSEND
 026B C9            370          RET
                    371 ;
                    372 ;**********************************************************************
                    373 ;
                    374 ;        ***  CORECT  ***
                    375 ;
                    376 ;   THIS ROUTINE RECEIVES AN ADDRESS PASSED TO IT CALLED DSTART WHICH IS
                    377 ;   THE START ADDRESS OF A 22 BYTE BLOCK OF DATA CONTAINING 11 DENSITY
```

```
 LOC  OBJ          LINE        SOURCE STATEMENT

                        ;   READINGS. CORECT THEN TAKES A 2-BYTE, 10-BIT CONVERSION AND PERFORMS
                        ;   A LINEAR REGRESSION CORRECTION ON THE VALUE. THE RESULT IS CONVERTED
                        ;   TO SIMPLE BCD FOR DISPLAY, AND RETURNED IN TDSTOR AS :
                        ;
                        ;                 TDSTOR+2   LSD   Z
                        ;                 TDSTOR+1         Y
                        ;                 TDSTOR     MSD   X        " X.YZ " FORMAT
                        ;
                        ;   THE EXPONENT RETURNED FROM FQFB2D ( FPAL ROUTINE ) IS TESTED FOR
                        ;   RANGE AND IF IN ERROR, ERROR CHARACTERS ARE RETURNED TO CALLING PROGRAM.
                        ;
                        ;***************************************************************************
                        ;
 026C 2A2200    D       CORECT: LHLD    MD0P
 026F 7E                        MOV     A,      M       ; CONVERT MD0 TO 32-BIT FLOATER.
 0270 321E00    D               STA     TFLOAT
 0273 23                        INX     H
 0274 7E                        MOV     A,      M
 0275 321F00    D               STA     TFLOAT+1
 0278 AF                        XRA     A
 0279 322000    D               STA     TFLOAT+2
 027C 322100    D               STA     TFLOAT+3
 027F 010800    D               LXI     B,      FPR     ; CONVERT
 0282 111E00    D               LXI     D,      TFLOAT
 0285 CD0000    E               CALL    FLTDS
 0288 CD0000    E               CALL    FSTOR           ; TFLOAT = FLOATER MD0.
 028B 2A5600    D       FLOATS: LHLD    BSTART
 028E 7E                        MOV     A,      M
 028F 320400    D               STA     TMPNUM          ; CONVERT MD TO 32-BIT FLOATER.
 0292 23                        INX     H
 0293 7E                        MOV     A,      M
 0294 320500    D               STA     TMPNUM+1
 0297 AF                        XRA     A
 0298 320600    D               STA     TMPNUM+2
 029B 320700    D               STA     TMPNUM+3
 029E 110400    D               LXI     D,      TMPNUM
 02A1 CD0000    E               CALL    FLTDS           ; CONVERTED MD RESIDES IN FAC.
 02A4 111E00    D       DOCOR:  LXI     D,      TFLOAT
 02A7 CD0000    E               CALL    FSUB            ; FAC = ( MD - MD0 )
 02AA 2A5200    D               LHLD    SLOPEP
 02AD EB                        XCHG
 02AE CD0000    E               CALL    FMUL            ; FAC = ( MD - MD0 ) X 1/SLOPE.
 02B1 3E03              RESULT: MVI     A, 03H          ; CONVERT RESULT TO DECIMAL FORMAT.
 02B3 325E00    D               STA     DLNGTH
 02B6 216100    D               LXI     H,      DECML
 02B9 225F00    D               SHLD    DADDB
 02BC 010800    D               LXI     B,      FPR
 02BF 115B00    D               LXI     D,      DSIGN
 02C2 CD0000    E               CALL    FQFB2D
 02C5 3A5B00    D       SCLTST: LDA     DSIGN           ; TEST FOR NEGATIVE RESULT.
 02C8 FE2B                      CPI     2BH             ; "2BH" IS ASCII FOR " + ".
 02CA C2DF02    C               JNZ     ITNEG
 02CD 3A5C00    D               LDA     DSCALE          ; GET DECIMAL EXPONENT.
 02D0 FEFE                      CPI     0FEH
```

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LOC  OBJ          LINE        SOURCE STATEMENT

02D2 CAED02    C   432           JZ      SHFT4           ; SHIFT POINT 4 PLACES.
02D5 FEFF          433           CPI     0FFH
02D7 CAFF02    C   434           JZ      SHFT3           ; SHIFT POINT 3 PLACES.
02DA FE00          435           CPI     00H
02DC CA1603    C   436           JZ      SHFT2           ; SHIFT POINT 2 PLACES.
02DF 3E00          437 ITNEG:    MVI     A,      00H     ; LOAD TDSTORS WITH ERROR CODE FOR DISPLAY.
02E1 325800    D   438           STA     TDSTOR          ; WHICH IS ALL ZEROS.
02E4 325900    D   439           STA     TDSTOR+1
02E7 325A00    D   440           STA     TDSTOR+2
02EA C32E03    C   441           JMP     INCREM          ; GO TO INCREMENT ROUTINE.
02ED AF            442 SHFT4:    XRA     A               ; LOAD 1ST & 2ND PLACES W/ZERO.
02EE 325800    D   443           STA     TDSTOR
02F1 325900    D   444           STA     TDSTOR+1
02F4 3A6100    D   445           LDA     DECML           ; GET LSD.
02F7 D630          446           SUI     30H             ; CONVERT FROM ASCII TO BCD.
02F9 325A00    D   447           STA     TDSTOR+2
02FC C32E03    C   448           JMP     INCREM
02FF AF            449 SHFT3:    XRA     A               ; LOAD 1ST PLACE W/ ZERO ONLY.
0300 325800    D   450           STA     TDSTOR
0303 3A6100    D   451           LDA     DECML
0306 D630          452           SUI     30H
0308 325900    D   453           STA     TDSTOR+1
030B 3A6200    D   454           LDA     DECML+1
030E D630          455           SUI     30H
0310 325A00    D   456           STA     TDSTOR+2
0313 C32E03    C   457           JMP     INCREM
0316 3A6100    D   458 SHFT2:    LDA     DECML
0319 D630          459           SUI     30H
031B 325800    D   460           STA     TDSTOR
031E 3A6200    D   461           LDA     DECML+1
0321 D630          462           SUI     30H
0323 325900    D   463           STA     TDSTOR+1
0326 3A6300    D   464           LDA     DECML+2
0329 D630          465           SUI     30H
032B 325A00    D   466           STA     TDSTOR+2
                   467 ;
032E 2A5600    D   468 INCREM:   LHLD    DSTART          ; INCREMENT ALL POINTERS USED IN THIS CALL.
0331 23            469           INX     H
0332 23            470           INX     H
0333 225600    D   471           SHLD    DSTART
0336 2A2200    D   472           LHLD    MDOP
0339 23            473           INX     H
033A 23            474           INX     H
033B 222200    D   475           SHLD    MDOP
033E 2A5200    D   476           LHLD    SLOPEP
0341 23            477           INX     H
0342 23            478           INX     H
0343 23            479           INX     H
0344 23            480           INX     H
0345 225200    D   481           SHLD    SLOPEP
0348 3A5800    D   482 NIBBLE:   LDA     TDSTOR          ; SET TDSTOR NIBBLE A = NIBBLE B.
034B 17            483           RAL
034C 17            484           RAL
034D 17            485           RAL
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LOC  OBJ          LINE        SOURCE STATEMENT

034E 17            486          RAL
034F E6F0          487          ANI     0F0H
0351 47            488          MOV     B,      A
0352 3A5800    D   489          LDA     TDSTOR
0355 B0            490          ORA     B
0356 325800    D   491          STA     TDSTOR
0359 3A5900    D   492          LDA     TDSTOR+1
035C 17            493          RAL
035D 17            494          RAL
035E 17            495          RAL
035F 17            496          RAL
0360 E6F0          497          ANI     0F0H
0362 47            498          MOV     B,      A
0363 3A5900    D   499          LDA     TDSTOR+1
0366 B0            500          ORA     B
0367 325900    D   501          STA     TDSTOR+1
036A 3A5A00    D   502          LDA     TDSTOR+2
036D 17            503          RAL
036E 17            504          RAL
036F 17            505          RAL
0370 17            506          RAL
0371 E6F0          507          ANI     0F0H
0373 47            508          MOV     B,      A
0374 3A5A00    D   509          LDA     TDSTOR+2
0377 B0            510          ORA     B
0378 325A00    D   511          STA     TDSTOR+2
037B C9            512          RET
                   513 ;
                   514 ;*************************************************************************
                   515 ;
                   516 ;        **  DSEND  **
                   517 ;
                   518 ;   DSEND SIMPLY SENDS THE 3 BYTE OF BCD DATA CONTAINED IN TDSTOR TO
                   519 ;   THE 33-DIGTI DISPLAY. IT IS UP TO THE CALLING PROGRAM TO SET THE
                   520 ;   DISPLAY RAM ADDRESS TO WHICH THE DATA IS TO BE WRITTEN. AUTO
                   521 ;   INCREMENT IS ALSO NOT ASSUMED.
                   522 ;
                   523 ;*************************************************************************
                   524 ;
037C CD6C02    C   525 DSEND:   CALL    CORECT
037F 2100B8        526          LXI     H,      DATA2
0382 3A5800    D   527          LDA     TDSTOR
0385 77            528          MOV     M,      A
0386 CD0000    E   529          CALL    DELAY
0389 3A5900    D   530          LDA     TDSTOR+1
038C 77            531          MOV     M,      A
038D CD0000    E   532          CALL    DELAY
0390 3A5A00    D   533          LDA     TDSTOR+2
0393 77            534          MOV     M,      A
0394 CD0000    E   535          CALL    DELAY
0397 C9            536          RET
                   537 ;
                   538 ;        DISPLAY MESSAGES FOLLOW:
                   539 ;
```

```
LOC  OBJ        LINE        SOURCE STATEMENT

0398 20          540 EMIT:   DB      20H      ; SPACE
0399 05          541 EMITM:  DB      05H      ; E
039A 0D          542         DB      0DH      ; M
039B 09          543         DB      09H      ; I
039C 14          544         DB      14H      ; T
039D 14          545         DB      14H      ; T
039E 05          546         DB      05H      ; E
039F 12          547         DB      12H      ; R
03A0 20          548         DB      20H      ; SPACE
03A1 03          549         DB      03H      ; C
03A2 01          550         DB      01H      ; A
03A3 0C          551         DB      0CH      ; L
03A4 3F          552         DB      3FH      ; ?
03A5 05          553 DMAX:   DB      05H      ; E
03A6 0E          554         DB      0EH      ; N
03A7 14          555         DB      14H      ; T
03A8 05          556         DB      05H      ; E
03A9 12          557         DB      12H      ; R
03AA 20          558         DB      20H      ; BLANK
03AB 04          559         DB      04H      ; D
03AC 20          560         DB      20H      ; BLANK
03AD 0D          561         DB      0DH      ; M
03AE 01          562         DB      01H      ; A
03AF 18          563         DB      18H      ; X
03B0 20          564 DZERO:  DB      20H      ; BLANK
03B1 12          565         DB      12H      ; R
03B2 05          566         DB      05H      ; E
03B3 01          567         DB      01H      ; A
03B4 04          568         DB      04H      ; D
03B5 20          569         DB      20H      ; BLANK
03B6 1A          570         DB      1AH      ; Z
03B7 05          571         DB      05H      ; E
03B8 12          572         DB      12H      ; R
03B9 0F          573         DB      0FH      ; O
03BA 12          574 RDDEN:  DB      12H      ; R
03BB 05          575         DB      05H      ; E
03BC 01          576         DB      01H      ; A
03BD 04          577         DB      04H      ; D
03BE 20          578         DB      20H      ; BLANK
03BF 04          579         DB      04H      ; D
03C0 20          580         DB      20H      ; BLANK
03C1 0D          581         DB      0DH      ; M
03C2 01          582         DB      01H      ; A
03C3 18          583         DB      18H      ; X
03C4 20          584 TEST:   DB      20H      ; BLANK
03C5 04          585         DB      04H      ; D
03C6 05          586         DB      05H      ; E
03C7 0E          587         DB      0EH      ; N
03C8 20          588         DB      20H      ; BLANK
03C9 12          589         DB      12H      ; R
03CA 05          590         DB      05H      ; E
03CB 01          591         DB      01H      ; A
03CC 04          592         DB      04H      ; D
                 593 ;
```

```
  LOC  OBJ        LINE        SOURCE STATEMENT

                   594         DSEG
                   595 ;
  0000             596 CLEARA:  DS      01H     ; CLEAR CODE FOR ENTRY TO KDSPY2.
  0001             597 CLEARB:  DS      01H     ; CLEAR CODE FOR EXIT FROM KDSPY2.
  0002             598 NXDRAM:  DS      02H     ; STORAGE LOCATION FOR NEXT DEN RAM POINTER.
  0004             599 TMPNUM:  DS      04H     ; TEMPOARY 32-BIT INTEGER STORAGE.
  0008             600 FPR:     DS      12H     ; 18 BYTE ALLOCATION FOR FLOATING POINT RECORD.
  001A             601 ADMAX:   DS      04H     ; FLOATER ADMAX.
  001E             602 TFLOAT:  DS      04H     ; FLOATER TEMP. STORAGE.
  0022             603 MDOP:    DS      02H     ; MEASURED ZERO DENSITY POINTER.
  0024             604 MDMAXP:  DS      02H     ; MEASURED D-MAX ADDRESS POINTER.
  0026             605 SLOPE:   DS      2CH     ; 44 BYTE BLOCK OF RAM FOR 11 SLOPE VALUES.
  0052             606 SLOPEP:  DS      02H     ; SLOPE ADDRESS POINTER STORAGE.
  0054             607 RAMPT:   DS      01H     ; RAM POINTER USED IN FINDING DATA BLOCKS.
  0055             608 SCNCNT:  DS      01H     ; SCAN COUNTER USED IN SCAN SUB-ROUTINE.
  0056             609 DSTART:  DS      02H     ; ADDRESS STORAGE FOR USE BY DSHOW AND CORECT.
  0058             610 TDSTOR:  DS      03H     ; TEMPORARY STORAGE FOR DISPLAY RESULTS.
  005B             611 DSIGN:   DS      01H     ; CONTROL BLOCK USED BY FQFR2D.
  005C             612 DSCALE:  DS      02H
  005E             613 DLNGTH:  DS      01H
  005F             614 DADDR:   DS      02H
  0061             615 DECML:   DS      03H
  0064             616 POS1:    DS      01H     ; PARAMETERS USED IN KDSPY2.
  0065             617 POS2:    DS      01H
  0066             618 RPOS1:   DS      01H
                   619 ;
                   620         END


PUBLIC SYMBOLS
ALPHA  A BF00   CLEARA D 0000   CLEARB D 0001   COMM1  A 1900   COMM2  A B801   DATA1  A 1800   DATA2  A B800
DRAM   A 8000   DSHOW  C 01DC   NXDRAM D 0002   PA1    A 0021   PB1    A 0022   PC1    A 0023   POS1   D 0064
POS2   D 0065   RAMPT  D 0054   RPA1   A 0000   RPA2   A 0008   RPB2   A 0009   RPOS1  D 0066   SCAN   C 010D
TDSTOR D 0058   TMPNUM D 0004

EXTERNAL SYMBOLS
DER    E 0000   DELAY  E 0000   DWRITE E 0000   FADD   E 0000   FCLR   E 0000   FDIV   E 0000   FERHND E 0000
FLOAD  E 0000   FLTDS  E 0000   FMUL   E 0000   FNEG   E 0000   FQFR2D E 0000   FSET   E 0000   FSTOR  E 0000
FSUB   E 0000   KDSPY2 E 0000   KDSPY3 E 0000   KSTOR1 E 0000   KSTOR2 E 0000   START  E 0000   SUM2   E 0000
SUM3   E 0000

USER SYMBOLS
ADMAX  D 001A   ALPHA  A BF00   BUSY   C 01B7   CALIB  C 0000   CALSLP C 0107   CKGCNT C 019F   CLEARA D 0000
CLEARB D 0001   COMM1  A 1900   COMM2  A B801   CORECT C 026C   COVRTS C 012F   CS1    A 0020   CS2    A 0028
DADDR  D 005F   DATA1  A 1800   DATA2  A B800   DER    E 0000   DECML  D 0061   DELAY  E 0000   DLNGTH D 005E
DMAX   C 03A5   DOCOR  C 02A4   DRAM   A 8000   DSCALE D 005C   DSEND  C 037C   DSHOW  C 01DC   DSIGN  D 005B
DSTART D 0056   DWRITE E 0000   DZERO  C 03B0   ECAL   C 0062   EMIT   C 0398   EMITH  C 0399   FADD   E 0000
FCLR   E 0000   FDIV   E 0000   FERHND E 0000   FINCAL C 010A   FIX    C 00A5   FLOAD  E 0000   FLOATS C 020B
FLTDS  E 0000   FMUL   E 0000   FNEG   E 0000   FPR    D 0008   FQFR2D E 0000   FSET   E 0000   FSTOR  E 0000
FSUB   E 0000   GDMAX  C 00B8   GZERO  C 00F9   INCREM C 032E   INHIBA C 024A   INHIBB C 0289   INIT   C 00AA
INKS   C 016D   ITNEG  C 02DF   KDSPY2 E 0000   KDSPY3 E 0000   KSTOR1 E 0000   KSTOR2 E 0000   LP1    C 01B9
LP2    C 01AF   MDOP   D 0022   MDOT   A 8017   MDMAXP D 0024   MDMAXT A 8001   NIBBLE C 0340   NX     C 01E2
NXDRAM D 0002   NXSLOP C 0113   OVER   C 01EF   PA1    A 0021   PA2    A 0029   PB1    A 0022   PB2    A 002A
PC1    A 0023   PC2    A 002B   POS1   D 0064   POS2   D 0065   RAMPT  D 0054   RDDA1  A 8002   RDDA2  A 800A
```

```
RDDB1  A 0003   RDDB2  A 000B   RDDEN  C 03BA   RDMAX  C 00DF   RESET  C 01D7   RESULT C 02B1   RPA1   A 0000
RPA2   A 0008   RPB1   A 0001   RPB2   A 0009   RPOS1  D 0066   SCAN   C 018D   SCLTST C 02C5   SCNCNT D 0055
SETIT  C 0078   SHFT2  C 0316   SHFT3  C 02FF   SHFT4  C 02ED   SLOPE  D 0026   SLOPEP D 0052   START  E 0000
SUM2   E 0008   SUM3   E 0000   T1HOB  A 0025   T1LOB  A 0024   T2HOB  A 002D   T2LOB  A 002C   TDSTOR D 0058
TEST   C 03C4   TFLOAT D 001E   TMPNUM D 0004

ASSEMBLY COMPLETE,   NO ERRORS
```

```
LOC  OBJ         LINE        SOURCE STATEMENT

                         ;*******************************************************************
                         ;
                         ;        Warm start routine for In-process IR Densitometer.
                         ;        Come here after calibration routine is complete.
                         ;        The first part of this routine prompts for the process
                         ;        date, then prints the date information on the 48 column
                         ;        printer.
                         ;
                         ;*******************************************************************
                         ;
                                  NAME    START
                         ;
                                  PUBLIC  DWRITE,PSEND,DELAY,START
                         ;
                                  EXTRN   COMM2,KDSPY2,KSTOR2,KSTOR1,ALPHA,COMM1,DATAIN,PA1,PB1,PC1
                         ;
                                  CSEG
                         ;
0000 210000    E         START:   LXI     H,      COMM2   ; CLEAR DENSITY DISPLAY.
0003 36DF                         MVI     M,      0DFH
0005 36A3                         MVI     M,      0A3H
0007 21E900    C                  LXI     H,      MONTH   ; SEND "ENTER MONTH:" TO DISPLAY.
000A 060D                         MVI     B,      0DH     ; LOAD # OF CHARACTERS.
000C CDA400    C                  CALL    DWRITE          ; WRITE MESSAGE.
000F CD0000    E                  CALL    KDSPY2          ; GET KEYBOARD ENTRIES.
0012 3E10                         MVI     A,      10H     ; CLEAR PRINTER CONTROLS.
0014 CDC300    C                  CALL    PSEND           ; SEND COMMAND TO PRINTER BUFFER.
0017 210C01    C                  LXI     H,      DATE    ; DATE POINTS TO "PROCESS DATE:"
001A 0E12                         MVI     C,      12H     ; LOAD CHARACTER COUNTER.
001C 0D                  PMESS1:  DCR     C               ; DECREMENT CHARACTER COUNTER.
001D 3E00                         MVI     A,      00H     ; PREPARE TO TEST COUNTER.
001F B9                           CMP     C               ; IF C=0, ZERO FLAG WILL SET.
0020 CA2B00    C                  JZ      DONE            ; IF NO MORE TO SEND, JUMP TO DONE.
0023 7E                           MOV     A,      M       ; PUT CHARACTER POINTED TO BY HL INTO A.
0024 CDC300    C                  CALL    PSEND           ; SEND IT TO PRINTER.
0027 23                           INX     H               ; INCREMENT TEXT POINTER.
0028 C31C00    C                  JMP     PMESS1
002B 3A0000    E         DONE:    LDA     KSTOR2          ; SEND MONTH DATA TO PRINTER.
002E C630                         ADI     30H             ; ADD 30 HEX TO GET ASCII CHARACTER.
0030 CDC300    C                  CALL    PSEND
0033 3A0000    E                  LDA     KSTOR1
0036 C630                         ADI     30H
0038 CDC300    C                  CALL    PSEND
003B 3E2F                         MVI     A,      2FH     ; SEND " / " TO PRINTER.
003D CDC300    C                  CALL    PSEND
0040 210000    E                  LXI     H,      ALPHA
0043 36E1                         MVI     M,      0E1H    ; BLANK ALPHA DISPLAY.
0045 CDDC00    C                  CALL    DELAY
0048 21F500    C                  LXI     H,      DAY     ; PROMPT "ENTER DAY:"
004B 060C                         MVI     B,      0CH     ; LOAD CHARACTER COUNTER.
004D CDA400    C                  CALL    DWRITE          ; WRITE TO DISPLAY.
0050 CD0000    E                  CALL    KDSPY2          ; GET 2 DIGIT KEY ENTRY.
0053 3A0000    E                  LDA     KSTOR2
```

```
LOC  OBJ          LINE        SOURCE STATEMENT

0056 C630           54          ADI      30H
0058 CDC300   C     55          CALL     PSEND             ; SEND DAY INFO TO PRINTER.
005B 3A0000   E     56          LDA      KSTOR1
005E C630           57          ADI      30H
0060 CDC300   C     58          CALL     PSEND
0063 3E2F           59          MVI      A,       2FH      ; SEND " / " TO PRINTER.
0065 CDC300   C     60          CALL     PSEND
0068 210000   E     61          LXI      H,       ALPHA
006B 36E1           62          MVI      M,       0E1H     ; BLANK ALPRA DISPLAY.
006D 210001   C     63          LXI      H,       YEAR     ; PROMPT "ENTER YEAR:".
0070 060D           64          MVI      B,       0DH      ; LOAD CHARACTER COUNTER.
0072 CDA400   C     65          CALL     DWRITE            ; WRITE TO DISPLAY.
0075 CD0000   E     66          CALL     KDSPY2            ; GET 2 DIGIT YEAR ENTRY FROM KEYBOARD.
0078 3A0000   E     67          LDA      KSTOR2            ; SEND YEAR DATA TO PRINTER.
007B C630           68          ADI      30H
007D CDC300   C     69          CALL     PSEND
0080 3A0000   E     70          LDA      KSTOR1
0083 C630           71          ADI      30H
0085 CDC300   C     72          CALL     PSEND
0088 210000   E     73 FINISH:  LXI      H,       COMM1    ; LOAD CONTROL DISPLAY COMMAND ADDRESS.
008B 36DC           74          MVI      M,       0DCH     ; BLANK THE CONTROL OISPLAY.
008D 3E17           75          MVI      A,       17H      ; " START TO PRINT " COMMAND.
008F CDC300   C     76          CALL     PSEND             ; PRINT THE DATE READER.
0092 3E17           77          MVI      A,       17H      ; SPACE NOW 3 BLANK LINES ON PRINTER.
0094 CDC300   C     78          CALL     PSEND
0097 3E17           79          MVI      A,       17H
0099 CDC300   C     80          CALL     PSEND
009C 3E17           81          MVI      A,       17H
009E CDC300   C     82          CALL     PSEND
00A1 C30000   E     83          JMP      DATAIN            ; GO TO DATAIN WHICH CONTAINS DATA ENTRY.
                    84 ;
                    85 ;        SUBROUTINES FOLLOW:
                    86 ;
                    87 DWRITE:  ; HL CONTAINS STARTING ADDRESS OF TEXT STRING TO BE SENT TO DISPLAY
                    88          ; B REGISTER CONTAINS THE STRING LENGTH. ALPHA DISPLAY WILL ALWAYS
                    89          ; BE SET TO BLANKS BEFORE MESSAGE IS WRITTEN.
                    90          ;
00A4 E5             91          PUSH     H                 ; STORE COPY OF HL ON STACK.
00A5 210000   E     92          LXI      H,       ALPHA
00A8 36E1           93          MVI      M,       0E1H
00AA CDDC00   C     94          CALL     DELAY
00AD 3600           95          MVI      M,       00H      ; SET CURSOR POSITION TO 0.
00AF CDDC00   C     96          CALL     DELAY
00B2 E1             97          POP      H                 ; RESTORE COPY OF HL REGISTERS.
00B3 05             98 AGAIN:   DCR      B                 ; DECREMENT CHARACTER COUNTER.
00B4 3E00           99          MVI      A,       00H      ; PREPARE A FOR CHARACTER COUNT TEST.
00B6 B8            100          CMP      B                 ; IF B=0, ZERO FLAG WILL SET.
00B7 C8            101          RZ                         ; IF B=0, THEN ALL DONE AND RETURN.
00B8 7E            102          MOV      A,       M        ; GET CHARACTER POINTED TO BY HL.
00B9 320000   E    103          STA      ALPHA             ; SENO IT TO ALPRA DISPLAY.
00BC 23            104          INX      H                 ; INCREMENT TEXT POINTER.
00BD CDDC00   C    105          CALL     DELAY
00C0 C3B300   C    106          JMP      AGAIN             ; GO DO IT AGAIN ASSROLE!
                   107 ;
```

```
 LOC  OBJ              SOURCE STATEMENT

                      ;
                      PSEND:  ; THIS ROUTINE IS USED TO SEND EITHER ONE BYTE OF DATA OR ONE
                              ; COMMAND TO THE 40 COLUMN LINE PRINTER. THE PRINTER BUSY STATUS
                              ; LINE IS POLLED AND A RETURN IS NOT MADE UNTIL A NOT BUSY STATUS
                              ; IS READ. THE BYTE TO BE SENT MUST BE PLACED IN THE A REGISTER
                              ; BEFORE CALLING PSEND. ( PRINTSEND ).
                              ;
 00C3 D300      E             OUT     LOW PA1         ; PUT A ONTO PRINTER DATA LINES.
 00C5 3E01                    MVI     A,      01H     ; BRING WR LINE HI.
 00C7 D300      E             OUT     LOW PB1
 00C9 3E00                    MVI     A,      00H     ; BRING WR LINE LOW.
 00CB D300      E             OUT     LOW PB1
 00CD 3E01                    MVI     A,      01H     ; BRING WR LINE HI AGAIN.
 00CF D300      E             OUT     LOW PB1
 00D1 CDDC00    C             CALL    DELAY
 00D4 DB00      E     PLOOK:  IN      LOW PC1         ; BRING IN PRINTER STATUS LINE.
 00D6 0F                      RRC
 00D7 0F                      RRC                     ; ROTATE BUSY BIT INTO CARRY POSITION.
 00D8 D0                      RNC                     ; IF NOT BUSY, NO CARRY AND RETURN.
 00D9 C3D400    C             JMP     PLOOK           ; OTHERWISE, KEEP LOOKING!
                      ;
                      ;
                      DELAY:  ; DELAY IS CALLED WHENEVER AN EXTERNAL DEVICE SUCH AS THE MTX-A1,
                              ; OR THE PRINTER REQUIRES EXCESS TIME TO SET ITSELF UP.
                              ;
 00DC 1602                    MVI     D,      02H
 00DE 1EFF            LOOP2:  MVI     E,      0FFH
 00E0 1D              LOOP1:  DCR     E
 00E1 C2E000    C             JNZ     LOOP1
 00E4 15                      DCR     D
 00E5 C2DE00    C             JNZ     LOOP2
 00E8 C9                      RET
                      ;
                      ;       DISPLAY MESSAGES FOLLOW:
                      ;
 00E9 05              MONTH:  DB      05H     ; E
 00EA 0E                      DB      0EH     ; N
 00EB 14                      DB      14H     ; T
 00EC 05                      DB      05H     ; E
 00ED 12                      DB      12H     ; R
 00EE 20                      DB      20H     ; BLANK
 00EF 0D                      DB      0DH     ; M
 00F0 0F                      DB      0FH     ; O
 00F1 0E                      DB      0EH     ; N
 00F2 14                      DB      14H     ; T
 00F3 08                      DB      08H     ; H
 00F4 3A                      DB      3AH     ; :
 00F5 20              DAY:    DB      20H     ; BLANK
 00F6 05                      DB      05H     ; E
 00F7 0E                      DB      0EH     ; N
 00F8 14                      DB      14H     ; T
 00F9 05                      DB      05H     ; E
 00FA 12                      DB      12H     ; R
 00FB 20                      DB      20H     ; BLANK
```

```
  LOC  OBJ        LINE        SOURCE STATEMENT

  00FC 04          162          DB      04H     ; D
  00FD 01          163          DB      01H     ; A
  00FE 19          164          DB      19H     ; Y
  00FF 3A          165          DB      3AH     ; :
  0100 20          166 YEAR:    DB      20H     ; BLANK
  0101 05          167          DB      05H     ; E
  0102 0E          168          DB      0EH     ; N
  0103 14          169          DB      14H     ; T
  0104 05          170          DB      05H     ; E
  0105 12          171          DB      12H     ; R
  0106 20          172          DB      20H     ; BLANK
  0107 19          173          DB      19H     ; Y
  0108 05          174          DB      05H     ; E
  0109 01          175          DB      01H     ; A
  010A 12          176          DB      12H     ; R
  010B 3A          177          DB      3AH     ; :
  010C 00          178 DATE:    DB      00H     ; BLANK
  010D 00          179          DB      00H     ; BLANK
  010E 00          180          DB      00H     ; BLANK
  010F 50          181          DB      50H     ; P
  0110 72          182          DB      72H     ; R
  0111 6F          183          DB      6FH     ; O
  0112 63          184          DB      63H     ; C
  0113 65          185          DB      65H     ; E
  0114 73          186          DB      73H     ; S
  0115 73          187          DB      73H     ; S
  0116 00          188          DB      00H     ; BLANK
  0117 44          189          DB      44H     ; D
  0118 61          190          DB      61H     ; A
  0119 74          191          DB      74H     ; T
  011A 65          192          DB      65H     ; E
  011B 3A          193          DB      3AH     ; :
  011C 00          194          DB      00H     ; BLANK
                   195 ;
                   196          END


PUBLIC SYMBOLS
DELAY  C 00DC   DWRITE C 00A4   PSEND  C 00C3   START  C 0000

EXTERNAL SYMBOLS
ALPHA  E 0000   COMM1  E 0000   COMM2  E 0000   DATAIN E 0000   KDSPY2 E 0000   KSTOR1 E 0000   KSTOR2 E 0000
PA1    E 0000   PB1    E 0000   PC1    E 0000

USER SYMBOLS
AGAIN  C 00B3   ALPHA  E 0000   COMM1  E 0000   COMM2  E 0000   DATAIN E 0000   DATE   C 010C   DAY    C 00F5
DELAY  C 00DC   DONE   C 002B   DWRITE C 00A4   FINISH C 0088   KDSPY2 E 0000   KSTOR1 E 0000   KSTOR2 E 0000
LOOP1  C 00E0   LOOP2  C 00DE   MONTH  C 00E9   PA1    E 0000   PB1    E 0000   PC1    E 0000   PLOOK  C 00D4
PMESS1 C 001C   PSEND  C 00C3   START  C 0000   YEAR   C 0100

ASSEMBLY COMPLETE,   NO ERRORS
```

```
LOC  OBJ              SOURCE STATEMENT

                      ;*************************************************************************
                      ;
                      ;       THIS PROGRAM INTERACTS WITH THE IR DENSITOMETER USER TO
                      ;       ALLOW FOR THE ENTRY OF THE THREE PROCESS TIME LENGTHS.
                      ;       ALSO TO BE ENTERED WITH THIS PROGRAM ARE THE INTERVAL-
                      ;       RATE COMBINATIONS USED IN THE DENSITY SCAN MEASURMENTS.
                      ;       USER INFORMATION WILL BE PRINTED ON THE LINE PRINTER AS
                      ;       IT IS ENTERED.
                      ;
                      ;*************************************************************************
                      ;
                              NAME    DATAIN
                      ;
                              PUBLIC  DATAIN,LDELAY,BINASC,DEB,IRCNT,PLBYTE
                              PUBLIC  IRBRAM,STABCT,MANFLG,MANMOD
                      ;
                              EXTRN   ALPHA,DELAY,PSEND,PWRITE,DWRITE,KDSPY2,KDSPY3
                              EXTRN   SUM2,SUM3,DEVNUM,PNTNUM,RPA2,CODEV
                      ;
                              CSEG
                      ;
0000 3EFD             DATAIN: MVI     A,      0FDH            ; RESET FTS TO AUTO MODE.
0002 D300       E             OUT     LOW   RPA2
0004 AF                       XRA     A               ; ZERO A REG.
0005 320000     D             STA     DEB             ; ZERO DEB (DATA ENTRY BYTE).
0008 320200     D             STA     STAB            ; ZERO SCAN TABULATION BYTE.
000B 210700     D             LXI     H,      IRCNT   ; ZERO I/R COUNT.
000E 23                       INX     H
000F 77                       MOV     M,      A
0010 23                       INX     H
0011 77                       MOV     M,      A
0012 23                       INX     H
0013 77                       MOV     M,      A
0014 210300     D             LXI     H,      PLBYTE  ; ZERO PROCESS LENGTH BYTES.
0017 23                       INX     R
0018 77                       MOV     M,      A
0019 23                       INX     H
001A 77                       MOV     M,      A
001B 23                       INX     B
001C 77                       MOV     M,      A
001D 322A00     D             STA     MANFLG          ; MANFLAG = 00H MEANS AUTO MODE.
0020 218703     C             LXI     H,      MANMOD  ; PROMPT "MANUAL MODE?"
0023 060D                     MVI     B,      0DH     ; LOAD TEXT COUNTER.
0025 CD0000     E             CALL    DWRITE          ; TO ALPHA DISPLAY.
0028 CD0000     E             CALL    KDSPY2          ; SUM2 = 0 MEANS AUTO, ANYTHING ELSE = MANUAL.
002B 3A0000     E             LDA     SUM2
002E FE00                     CPI     00H
0030 CA5300     C             JZ      FRONT           ; IF NOT MANUAL, GO WITH NORMAL ENTRY ROUTINE.
0033 3EFE                     MVI     A,      0FEH    ; ENABLE FTS CONTROL FOR MANUAL SELECT.
0035 D300       E             OUT     LOW RPA2
0037 219303     C             LXI     H,      PNTMAN  ; PRINT "MANUAL MODE SELECTED."
003A 0E22                     MVI     C,      22H     ; LOAD TEXT COUNTER.
003C CD0000     E             CALL    PWRITE          ; WRITE TO PRINTER.
```

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 LOC  OBJ         LINE        SOURCE STATEMENT

 003F 3E17          54          MVI    A,      17H     ; PRINT BUFFER CONTENTS.
 0041 CD0000   E    55          CALL   PSEND
 0044 3E17          56          MVI    A,      17H     ; SPACE TWO LINES.
 0046 CD0000   E    57          CALL   PSEND
 0049 3E17          58          MVI    A,      17H
 004B CD0000   E    59          CALL   PSEND
 004E 3EFF          60          MVI    A,      0FFH
 0050 322A00   D    61          STA    MANFLG          ; SET MANFLG = FFH TO MEAN MANUAL MODE SELECTED
 0053 AF            62 FRONT:   XRA    A               ; ZERO A REG AGAIN.
 0054 320100   D    63          STA    ITAB            ; ITAB MUST BE ZEROED EVERY PASS THRU I/R IN.
 0057 3A0000   D    64          LDA    DEB
 005A E60F          65          ANI    0FH             ; I/R COUNTER MUST BE RESET TO 0.
 005C 47            66          MOV    B,      A       ; STORE COPY OF A REG.
 005D 212B00   D    67          LXI    H,      STABCT  ; FORM SUCESSIVE SCAN TABS, DEPENDING ON
 0060 85            68          ADD    L               ; NUMBER OF PROCESSES DESIRED.
 0061 6F            69          MOV    L,      A
 0062 3A0200   D    70          LDA    STAB
 0065 77            71          MOV    M,      A
 0066 78            72          MOV    A,      B       ; RETREIVE A.
 0067 C601          73          ADI    01H             ; INCREMENT LO-ORDER NIBBLE OF DEB.
 0069 320000   D    74          STA    DEB             ; UP-DATE DEB.
 006C FE04          75          CPI    04H             ; TEST TO SEE IF PROCESS ENTRY IS DONE.
 006E CA0000   E    76          JZ     GODEV           ; IF ZERO SETS, JUMP TO START PROCESS ROUTINE.
 0071 CD0000   E    77          CALL   DEVNUM          ; PROMPT "PROCESS [LO-DEB] = ?".
 0074 CD0000   E    78 OMT:     CALL   KDSPY3          ; GET THREE DIGIT PROCESS ENTRY.
 0077 3A0000   E    79          LDA    SUM3            ; TEST FOR ALLOWABLE PROCESS LENGTH.
 007A FE7F          80          CPI    7FH             ; 127 MINUTES IS MAX. LENGTH FOR PROCESS.
 007C DA8A00   C    81          JC     PASS            ; IF CY SETS, THEN SUM3 < 7FH.
 007F 3ECB          82          MVI    A,      0CBH    ; COME HERE IF GREATER, AND SET ERROR MODE.
 0081 320000   E    83          STA    ALPHA           ; START ALPHA DISPLAY BLINKING.
 0084 CD0000   E    84          CALL   DELAY
 0087 C37400   C    85          JMP    OMT             ; GO AND GET ANOTHER PROCESS ENTRY.
 008A 210300   D    86 PASS:    LXI    H,      PLBYTE  ; LOAD HL WITH STARTING PLB ADDRESS.
 008D 3A0000   D    87          LDA    DEB             ; GET LO-ORDER PORTION OF DATA ENTRY BYTE.
 0090 E60F          88          ANI    0FH             ; MASK OUT HI-ORDER NIBBLE.
 0092 85            89          ADD    L               ; ADD LOB OF PLBYTE TO PROCESS ENTRY COUNT.
 0093 6F            90          MOV    L,      A       ; PLACE RESULT INTO L REG.
 0094 3A0000   E    91          LDA    SUM3            ; GET ENTERED PROCESS LENGTH FROM STORAGE.
 0097 77            92          MOV    M,      A       ; STORE VALUE IN PLBYTE(1,2,3).
 0098 CD0000   E    93          CALL   PNTNUM          ; PRINT "PROCESS [LO-DEB] = [KSTOR1,2,3] MIN"
 009B 3A0000   E    94          LDA    SUM3
 009E FE00          95          CPI    00H             ; TEST TO SEE IF ENTERED PROCESS LENGTH = 0.
 00A0 CAE001   C    96          JZ     NEXT            ; IF SUM3=0, NO NEED TO GO TO INTERVAL ENTRY.
                    97                                 ; SO RETURN FOR NEXT PROCESS ENTRY.
 00A3 3A0200   D    98 RATEIN:  LDA    STAB
 00A6 FEBA          99          CPI    0BAH            ; COMPARE CURRENT STAB TO MAX. SCAN #.
 00A8 CAA201   C   100          JZ     SCNOUT          ; IF STAB = MAX. #, THEN PROMPT "OUT OF SCANS#
 00AB 3A0000   D   101          LDA    DEB             ; GET DATA ENTRY BYTE(DEB)
 00AE C610         102          ADI    10H             ; INCREMENT HI-ORDER NIBBLE(INTERVAL/RATE).
 00B0 320000   D   103          STA    DEB             ; STORE UPDATED VERSION OF DEB.
 00B3 E6F0         104          ANI    0F0H            ; MASK OUT LO-ORDER NIBBLE.
 00B5 FEA0         105          CPI    0A0H            ; ALLOW ONLY 10 INTERVAL/RATE ENTERIES.
 00B7 CAE001   C   106          JZ     NEXT            ; IF 10 I/R REACHED, GO TO NEXT PROCESS ENTRY.
 00BA CDE702   C   107          CALL   IRVNUM          ; PROMPT "INTERVAL [HI-DEB] = ? ".
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 LOC  OBJ          LINE        SOURCE STATEMENT

00BD CD0000    E    108 OMTA:   CALL    KDSPY2              ; GET TWO DIGIT INTERVAL ENTRY.
00C0 3A0000    E    109         LDA     SUM2                ; TEST VALUE OF SUM2.
00C3 FE00           110         CPI     00H                 ; IS IT = TO 0?
00C5 CAE001    C    111         JZ      NEXT                ; IF ZERO, TEST FOR MANUAL MODE.
00C8 CDD301    C    112         CALL    RAMCNT              ; GET 2(SUM OF IRCNTS)
00CB 3A0000    D    113         LDA     DEB                 ; IRBRAM = INTRVAL RATE BYTE RAM.
00CE E6F0           114         ANI     0F0H                ; MASK TO GET HI-ORDER NIBBLE ONLY.
00D0 0F             115         RRC                         ; ROTATE 3 TIMES TO GET IT INTO LOW POSITION.
00D1 0F             116         RRC
00D2 0F             117         RRC
00D3 80             118         ADD     B                   ; A NOW =2[HI-DEB] + 2(SUM OF IRCNTS).
00D4 210B00    D    119         LXI     H,      IRBRAM
00D7 85             120         ADD     L
00D8 6F             121         MOV     L,      A           ; HL = 2[HI-DEB] + 2(SUM OF IRCNTS) + IRBRAM
00D9 3A0000    E    122         LDA     SUM2                ; SUM2 = LAST INTERVAL ENTRY.
00DC 77             123         MOV     M,      A           ; STORE IT AT HL POINTER.
00DD 3A0100    D    124         LDA     ITAB                ; LOAD A WITH WITH RUNNING INTERVAL SUM, ITAB.
00E0 86             125         ADD     M                   ; A = SUM2 + ITAB
00E1 320100    D    126         STA     ITAB                ; UPDATE ITAB.
00E4 47             127         MOV     B,      A           ; STORE COPY OF ITAB IN B REG.
00E5 3A0000    E    128         LDA     SUM3                ; SUM3 SHOULD STILL CONTAIN PLB[LO-DEB].
00E8 B8             129         CMP     B                   ; A=SUM3 COMPARED TO B=ITAB.
00E9 DA0501    C    130         JC      EDBLNK              ; IF CY=1, A(B, SUM3(ITAB, ERROR.
00EC C21B01    C    131         JNZ     LESS                ; IF NO CY AND NO ZERO, ITAB(PROCESS LENGTH.
00EF 3EE1           132         MVI     A,      0E1H        ; IF COME HERE, THEN ITAB=SUM3.
00F1 320000    E    133         STA     ALPHA               ; CLEAR ALPHA DISPLAY.
00F4 CD0000    E    134         CALL    DELAY
00F7 21FE01    C    135         LXI     H,      PFULL       ; HL POINTS TO PROCESS FULL MESSAGE.
00FA 060D           136         MVI     B,      0DH         ; LOAD CHARACTER COUNTER.
00FC CD0000    E    137         CALL    DWRITE              ; WRITE TO ALPHA DISPLAY.
00FF CD7403    C    138         CALL    LDELAY              ; PAUSE FOR 5 SEC.
0102 C31B01    C    139         JMP     LESS                ; GO TO RATE ENTRY ROUTINE.
0105 3A0000    E    140 EDBLNK: LDA     SUM2                ; LAST INTERVAL ENTRY TO BE SUBTRACTED
0108 47             141         MOV     B,      A           ; FROM ITAB, THEN ITAB UPDATED.
0109 3A0100    D    142         LDA     ITAB
010C 90             143         SUB     B
010D 320100    D    144         STA     ITAB
0110 3ECB           145         MVI     A,      0CBH        ; CAUSE ALPHA DISPLAY TO BLINK.
0112 320000    E    146         STA     ALPHA
0115 CD0000    E    147         CALL    DELAY
0118 C3BD00    C    148         JMP     OMTA                ; GO AND GET ANOTHER INTERVAL ENTRY.
011B CD3B03    C    149 LESS:   CALL    RATNUM              ; PROMPT "RATE [HI-DEB] = ?"
011E CD0000    E    150 OMTYA:  CALL    KDSPY2              ; GET 2-DIGIT RATE ENTRY.
0121 3A0000    E    151         LDA     SUM2                ; PUT RATE ENTRY INTO A REG.
0124 FE00           152         CPI     00H                 ; RATE ENTRIES OF 00 ARE NOT ALLOWED.
0126 CA3001    C    153         JZ      INVLID
0129 47             154         MOV     B,      A           ; STORE COPY IN B REG.
012A 3E3C           155         MVI     A,      3CH         ; LOAD A WITH MAX. RATE (60 SCANS/MIN.).
012C B8             156         CMP     B                   ; A=MAX. RATE CMP TO B=ENTERED RATE.
012D D23B01    C    157         JNC     PASSA               ; IF CY SETS, RATE)MAX. SO BLINK DISPLAY.
0130 3ECB           158 INVLID: MVI     A,      0CBH        ; LOAD BLINK CODE.
0132 320000    E    159         STA     ALPHA
0135 CD0000    E    160         CALL    DELAY
0138 C31E01    C    161         JMP     OMTYA               ; GO AND GET ANOTHER RATE ENTRY.
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 LOC  OBJ         LINE        SOURCE STATEMENT

 013B CDD301   C   162 PASSA:  CALL    RAMCNT
 013E 3A0000   D   163         LDA     DEB
 0141 E6F0         164         ANI     0F0H             ; MASK OUT LO-ORDER NIBBLE.
 0143 0F           165         RRC                      ; ROTATE 3 TIMES TO GET INTO LOW POSITION.
 0144 0F           166         RRC
 0145 0F           167         RRC
 0146 80           168         ADD     B
 0147 D601         169         SUI     01H              ; SUBTRACT ONE TO GET ONE BELOW ILB.
 0149 210B00   D   170         LXI     H,      IRBRAM
 014C 85           171         ADD     L                ; ADD 2(SUM OF IRCNTS) - 1 + IRBRAM +2[HI-DEB]
 014D 6F           172         MOV     L,      A        ; HL = IRBRAM - 1 + 2[HI-DEB] +2(SUM OF IRCNTS)
 014E 3A0000   E   173         LDA     SUM2             ; SUM2 IS SPB[HI-DEB].
 0151 77           174         MOV     M,      A        ; STORE SUM2 (RATE) AT THIS HL LOCATION.
                   175 ;
                   176 ;       NOW CALCULATE PRODUCT OF ILB[HI-DEB] X SPB[HI-DEB]. THAT IS,
                   177 ;       INTERVAL LENGTH TIMES SCAN RATE EQUALS TOTAL SCANS GENERATED.
                   178 ;
 0152 AF           179         XRA     A                ; ZERO A REG.
 0153 57           180         MOV     D,      A
 0154 5F           181         MOV     E,      A        ; ZERO DE REG. PAIR.
 0155 7E           182         MOV     A,      M        ; A = SPB ( LAST RATE ENTRY ).
 0156 23           183         INX     H                ; HL NOW POINTS TO ILB ( LAST INTERVAL ENTRY )
 0157 FE00         184         CPI     00H              ; IF SCAN RATE ENTBY = 0, JMP TO SMORE.
 0159 CA6601   C   185         JZ      PASS2
 015C 46           186 HERE:   MOV     B,      M        ; B = ILB.
 015D 13           187 MORE:   INX     D                ; DE IS MULTI. COUNTER.
 015E 05           188         DCR     B
 015F C25D01   C   189         JNZ     MORE             ; DE GETS INCREMENTED BY ILB.
 0162 3D           190         DCR     A
 0163 C25C01   C   191         JNZ     HERE             ; DE GETS INCREMENTED BY ILB, SPB TIMES.
 0166 3A0200   D   192 PASS2:  LDA     STAB
 0169 FE00         193         CPI     00H              ; IF SCAN TABULATION = 00H, JUMP OVER SMORE.
 016B CA7301   C   194         JZ      PASS3
 016E 13           195 SMORE:  INX     D
 016F 3D           196         DCR     A
 0170 C26E01   C   197         JNZ     SMORE            ; DE GETS INCREMENTED STAB TIMES.
                   198 ;
                   199 ;       DE NOW EQUALS THE # OF SCANS THAT WOULD BE GENERATED W/RATE ENTERED
                   200 ;
 0173 BA           201 PASS3:  CMP     D                ; A=0. IF D)0, THEN RATE ENTRY TOO BIG.
 0174 C2B201   C   202         JNZ     RATBIG
 0177 43           203         MOV     B,      E        ; E CONTAINS 1 BYTE SCAN TABULATION.
 0178 3EBA         204         MVI     A,      0BAH     ; MAX. SCANS AVAILABLE = 186.
 017A B8           205         CMP     B
 017B CA9301   C   206         JZ      NOMORE           ; IF =, PROMPT "OUT OF SCANS", UPDATE STAB.
 017E DAB201   C   207         JC      RATBIG           ; IF CY SETS, RATE TOO BIG.
 0181 78           208         MOV     A,      B        ; A = SCAN TABULATION.
 0182 320200   D   209         STA     STAB
 0185 CD2202   C   210 PRINT:  CALL    PNTIR            ; COME HERE IF LESS THAN MAXIMUM.
                   211                                  ; AND PRINT INTERVAL/RATE INFO ON PRINTER.
 0188 3A0200   D   212         LDA     STAB             ; TEST TO SEE IF WE HAVE SCANS REMAINING.
 018B FEBA         213         CPI     0BAH             ; COMPARE STAB TO MAX. NUMBER.
 018D DAA300   C   214         JC      RATEIN           ; CY WILL SET IF SCANS REMAINING.
 0190 C3E001   C   215         JMP     NEXT             ; IF NONE LEFT, GO TO NEXT PROCESS ENTRY.
```

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LOC  OBJ              SOURCE STATEMENT

0193 7B           NOMORE: MOV    A,      E       ; PUT SCAN TABULATION INTO A REG.
0194 320200   D           STA    STAB
0197 CD2202   C           CALL   PNTIR           ; PRINT I/R INFO.
019A 3A0000   D           LDA    DEB
019D C610                 ADI    10H             ; INCREMENT [HI-DEB]
019F 320000   D           STA    DEB             ; UPDATE DEB
01A2 E5           SCNOUT: PUSH   H
01A3 210A02   C           LXI    H,      OUTINT  ; START ADDRESS OF "OUT OF SCANS"
01A6 060D                 MVI    B,      0DH     ; LOAD TEXT COUNTER.
01A8 CD0000   E           CALL   DWRITE          ; WRITE TO DISPLAY.
01AB E1                   POP    H
01AC CD7403   C           CALL   LDELAY          ; PAUSE FOR 5 SECONDS.
01AF C3E001   C           JMP    NEXT            ; GO STORE IRCNTS THEN GO TO NEXT PROCESS.
01B2 211602   C   RATBIG: LXI    H,      TOOBIG  ; START ADDRESS OF "RATE TOO BIG".
01B5 060D                 MVI    B,      0DH     ; LOAD TEXT COUNTER.
01B7 CD0000   E           CALL   DWRITE
01BA CD7403   C           CALL   LDELAY          ; PAUSE FOR ~5 SEC.
01BD 3ECB                 MVI    A,      0CBH    ; LOAD BLINK CODE.
01BF 320000   E           STA    ALPHA
01C2 CD0000   E           CALL   DELAY
01C5 C31E01   C           JMP    ONTYA           ; GO AND GET ANOTHER RATE ENTRY.
01C8 3A2A00   D   MANTST: LDA    MANFLG          ; TEST TO SEE IF IN MANUAL MODE.
01CB FEFF                 CPI    0FFH
01CD CA0000   E           JZ     GODEV           ; RECALL MANFLG=FFH MEANS MANUAL MODE.
01D0 C35300   C           JMP    FRONT           ; SKIP MANUAL MODE TEST FOR NOW.
                  ;
                  ;*********************************************************************
                  ;
                  ;       THIS SUBROUTINE TAKES IRBRAM ADDRESS AND DOES THIS:
                  ;               IRBRAM POINTER = 2(SUM OT IRCNTS)  RETURNED IN B REG.
                  ;
                  ;*********************************************************************
                  ;
01D3 AF           RAMCNT: XRA    A               ; ZERO A REG.
01D4 210700   D           LXI    H,      IRCNT
01D7 23                   INX    H
01D8 86                   ADD    M               ; ADD PROCESS 1 I/R COUNT TO A.
01D9 23                   INX    H
01DA 86                   ADD    M               ; ADD PROCESS 2 I/R COUNT TO A.
01DB 23                   INX    H
01DC 86                   ADD    M               ; ADD PROCESS 3 I/R COUNT TO A.
01DD 07                   RLC                    ; MULTIPLY SUM OF I/R COUNTS BY 2.
01DE 47                   MOV    B,      A
01DF C9                   RET
                  ;
01E0 3A0000   D   NEXT:   LDA    DEB
01E3 E60F                 ANI    0FH             ; GET PROCESS COUNT.
01E5 210700   D           LXI    H,      IRCNT   ; START ADDRESS OF I/R COUNT STORAGE.
01E8 85                   ADD    L
01E9 6F                   MOV    L,      A       ; HL NOW POINTS TO IRCNT [LO-DEB].
01EA 3A0000   D           LDA    DEB
01ED E6F0                 ANI    0F0H            ; GET I/R COUNT.
01EF 0F                   RRC
01F0 0F                   RRC
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LOC  OBJ            LINE        SOURCE STATEMENT

01F1 0F                          RRC
01F2 0F                          RRC
01F3 FE00                        CPI     00B
01F5 CAFA01    C                 JZ      STORE
01F8 D601                        SUI     01B
01FA 77                    STORE: MOV    M,      A        ; STORE I/R COUNT WHER HL POINTS.
01FB C3C801    C                 JMP     MANTST
                           ;
                           ;     MESSAGE TABLES FOLLOW.
                           ;
01FE 10                    PFULL: DB     10H     ; P
01FF 12                          DB      12H     ; R
0200 0F                          DB      0FH     ; O
0201 03                          DB      03H     ; C
0202 05                          DB      05H     ; E
0203 13                          DB      13H     ; S
0204 13                          DB      13H     ; S
0205 20                          DB      20H     ; SPACE
0206 06                          DB      06H     ; F
0207 15                          DB      15H     ; U
0208 0C                          DB      0CH     ; L
0209 0C                          DB      0CH     ; L
020A 0F                    OUTINT: DB    0FH     ; O
020B 15                          DB      15H     ; U
020C 14                          DB      14H     ; T
020D 20                          DB      20H     ; SPACE
020E 0F                          DB      0FH     ; O
020F 06                          DB      06H     ; F
0210 20                          DB      20H     ; SPACE
0211 13                          DB      13H     ; S
0212 03                          DB      03H     ; C
0213 01                          DB      01H     ; A
0214 0E                          DB      0EH     ; N
0215 13                          DB      13H     ; S
0216 12                    TOOBIG: DB    12H     ; R
0217 01                          DB      01H     ; A
0218 14                          DB      14H     ; T
0219 05                          DB      05H     ; E
021A 20                          DB      20H     ; SPACE
021B 14                          DB      14H     ; T
021C 0F                          DB      0FH     ; O
021D 0F                          DB      0FH     ; O
021E 20                          DB      20H     ; SPACE
021F 02                          DB      02H     ; B
0220 09                          DB      09H     ; I
0221 07                          DB      07H     ; G
                           ;
                           ;     SUBROUTINES FOLLOW:
                           ;
                           ;***************************************************************************
                           ;
                           ;     THIS ROUTINE TAKES THE CURRENT CONTENTS OF THE HI-ORDER NIBBLE
                           ;     OF DEB (INTERVAL/RATE COUNTER) AND PRINTS IT ON THE LINE PRINTER
                           ;     IN THE FOLLOWING FORMAT:
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 LOC  OBJ         LINE        SOURCE STATEMENT

                   324 ;
                   325 ;        " INTERVAL [HI-DEB] = ILB [HI-DEB] MINUTES "
                   326 ;
                   327 ;        "     RATE [HI-DEB] = SPB [HI-DEB] SCANS/MINUTE "
                   328 ;
                   329 ;        WHEN CALLED, IT IS ASSUMED THAT HL IS POINTING TO ILB [HI-DEB].
                   330 ;
                   331 ;*********************************************************************
                   332 ;
0222 E5            333 PNTIR:   PUSH    H                ; SAVE COPY OF HL AS DESTROYED IN CALLS.
0223 21BA02   C    334          LXI     H,      D1TAB    ; START ADDRESS OF "INTERVAL".
0226 0E0E          335          MVI     C,      0EH      ; LOAD TEXT COUNTER.
0228 CD0000   E    336          CALL    PWRITE
022B 3A0000   D    337          LDA     DEB
022E E6F0          338          ANI     0F0H             ; MASK OUT LOW-ORDER NIBBLE.
0230 0F            339          RRC                      ; ROTATE HON TO LON.
0231 0F            340          RRC
0232 0F            341          RRC
0233 0F            342          RRC
0234 CD2203   C    343          CALL    BINASC           ; CONVERT I/R COUNTER TO 2 ASCII CHARACTERS.
0237 7A            344          MOV     A,      D        ; PUT 10'S PLACE INTO A REG.
0238 CD0000   E    345          CALL    PSEND
023B 79            346          MOV     A,      C        ; PUT 1'S PLACE INTO A REG.
023C CD0000   E    347          CALL    PSEND
023F 3E20          348          MVI     A,      20H      ; SEND A SPACE.
0241 CD0000   E    349          CALL    PSEND
0244 3E3D          350          MVI     A,      3DH      ; SEND "=" TO PRINTER.
0246 CD0000   E    351          CALL    PSEND
0249 3E20          352          MVI     A,      20H      ; SEND ANOTHER SPACE.
024B CD0000   E    353          CALL    PSEND
024E E1            354          POP     H                ; RETRIVE COPY OF HL.
024F 7E            355          MOV     A,      M        ; HL STILL POINTS TO ILB[HI-DEB].
0250 E5            356          PUSH    H                ; SAVE COPY AGAIN.
0251 CD2203   C    357          CALL    BINASC           ; CONVERT INTERVAL LENGTH TO ASCII.
0254 7A            358          MOV     A,      D        ; GET 10'S.
0255 CD0000   E    359          CALL    PSEND
0258 79            360          MOV     A,      C        ; GET 1'S.
0259 CD0000   E    361          CALL    PSEND
025C 21C602   C    362          LXI     H,      MINUTE   ; LOAD START ADDRESS OF "MINUTES".
025F 0E0A          363          MVI     C,      0AH      ; LOAD TEXT COUNTER.
0261 CD0000   E    364          CALL    PWRITE
0264 3E17          365          MVI     A,      17H      ; NOW PRINT PRINTER BUFFER CONTENTS.
0266 CD0000   E    366          CALL    PSEND
                   367 ;
                   368 ;        NOW PRINT RATE INFORMATION
                   369 ;
0269 21CE02   C    370          LXI     H,      D2TAB    ; START ADDRESS OF "RATE".
026C 0E0E          371          MVI     C,      0EH      ; LOAD TEXT COUNTER.
026E CD0000   E    372          CALL    PWRITE
0271 3A0000   D    373          LDA     DEB
0274 E6F0          374          ANI     0F0H             ; MASK OUT LO-ORDER NIBBLE.
0276 0F            375          RRC
0277 0F            376          RRC
0278 0F            377          RRC
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 LOC  OBJ         LINE        SOURCE STATEMENT

0279 0F            378         RRC
027A CD2203    C   379         CALL    BINASC            ; CONVERT I/R COUNT TO ASCII.
027D 7A            380         MOV     A,      D         ; GET 10'S.
027E CD0000    E   381         CALL    PSEND
0281 79            382         MOV     A,      C         ; GET 1'S.
0282 CD0000    E   383         CALL    PSEND
0285 3E20          384         MVI     A,      20H       ; SEND SPACE.
0287 CD0000    E   385         CALL    PSEND
028A 3E3D          386         MVI     A,      3DH       ; SEND "=" TO PRINTER.
028C CD0000    E   387         CALL    PSEND
028F 3E20          388         MVI     A,      20H       ; SEND ANOTHER SPACE.
0291 CD0000    E   389         CALL    PSEND
0294 E1            390         POP     H
0295 2B            391         DCX     H                 ; INCREMENT HJ TO SPB[HI-DEB].
0296 7E            392         MOV     A,      M         ; GET SPB.
0297 CD2203    C   393         CALL    BINASC            ; CONVERT TO ASCII.
029A 7A            394         MOV     A,      D
029B CD0000    E   395         CALL    PSEND
029E 79            396         MOV     A,      C
029F CD0000    E   397         CALL    PSEND
02A2 21DA02    C   398         LXI     H,      SCNMIN  ; START ADDRESS OF "SCAN/MINUTES".
02A5 0E0E          399         MVI     C,      0EH       ; LOAD TEXT COUNTER.
02A7 CD0000    E   400         CALL    PWRITE
02AA 3E17          401         MVI     A,      17H       ; PRINT PRINTER BUFFER CONTENTS.
02AC CD0000    E   402         CALL    PSEND
02AF 3E17          403         MVI     A,      17H       ; SPACE ONE BLANK LINE.
02B1 CD0000    E   404         CALL    PSEND
02B4 3E17          405         MVI     A,      17H       ; SPACE ONE BLANK LINE.
02B6 CD0000    E   406         CALL    PSEND
02B9 C9            407         RET                       ; RETURN TO CALLING PROGRAM.
                   408 ;
                   409 ;       MESSAGE TABLES FOLLOW:
                   410 ;
02BA 20            411 D1TAB:  DB      20H     ; SPACE
02BB 20            412         DB      20H     ; SPACE
02BC 20            413         DB      20H     ; SPACE
02BD 49            414         DB      49H     ; I
02BE 6E            415         DB      6EH     ; N
02BF 74            416         DB      74H     ; T
02C0 65            417         DB      65H     ; E
02C1 72            418         DB      72H     ; R
02C2 76            419         DB      76H     ; V
02C3 61            420         DB      61H     ; A
02C4 6C            421         DB      6CH     ; L
02C5 20            422         DB      20H     ; SPACE
02C6 20            423 MINUTE: DB      20H     ; SPACE
02C7 6D            424         DB      6DH     ; M
02C8 69            425         DB      69H     ; I
02C9 6E            426         DB      6EH     ; N
02CA 75            427         DB      75H     ; U
02CB 74            428         DB      74H     ; T
02CC 65            429         DB      65H     ; E
02CD 73            430         DB      73H     ; S
02CE 20            431 D2TAB:  DB      20H     ; SPACE
```

```
 LOC  OBJ           LINE        SOURCE STATEMENT

 02CF 20             432          DB       20H      ; SPACE
 02D0 20             433          DB       20H      ; SPACE
 02D1 20             434          DB       20H      ; SPACE
 02D2 20             435          DB       20H      ; SPACE
 02D3 20             436          DB       20H      ; SPACE
 02D4 20             437          DB       20H      ; SPACE
 02D5 52             438          DB       52H      ; R
 02D6 61             439          DB       61H      ; A
 02D7 74             440          DB       74H      ; T
 02D8 65             441          DB       65H      ; E
 02D9 20             442          DB       20H      ; SPACE
 02DA 20             443 SCNMIN:  DB       20H      ; SPACE
 02DB 73             444          DB       73H      ; S
 02DC 63             445          DB       63H      ; C
 02DD 61             446          DB       61H      ; A
 02DE 6E             447          DB       6EH      ; N
 02DF 73             448          DB       73H      ; S
 02E0 2F             449          DB       2FH      ; /
 02E1 6D             450          DB       6DH      ; M
 02E2 69             451          DB       69H      ; I
 02E3 6E             452          DB       6EH      ; N
 02E4 75             453          DB       75H      ; U
 02E5 74             454          DB       74H      ; T
 02E6 65             455          DB       65H      ; E
                     456 ;
                     457 ;*********************************************************************
                     458 ;
                     459 ;         THIS ROUTINE TAKES THE VALUE OF THE HI-ORDER NIBBLE STORED AT
                     460 ;         DEB AND DISPLAYS IT ON THE ALPHA DISPLAY AS:
                     461 ;
                     462 ;         " INTERVAL [HI-DEB] = ? "
                     463 ;
                     464 ;         CALLS DWRITE AND DELAY.
                     465 ;
                     466 ;*********************************************************************
                     467 ;
 02E7 3EE1           468 IRVNUM:  MVI      A,       0E1H     ; BLANK ALPHA DISPLAY.
 02E9 320000    E    469          STA      ALPHA
 02EC CD0000    E    470          CALL     DELAY
 02EF 211903    C    471          LXI      H,       IRVTAB   ; LOAD START ADDRESS OF MESSAGE.
 02F2 060A           472          MVI      B,       0AH      ; LOAD TEXT COUNTER.
 02F4 CD0000    E    473          CALL     DWRITE             ; WRITE TO DISPLAY.
 02F7 3A0000    D    474          LDA      DEB
 02FA E6F0           475          ANI      0F0H               ; MASK OUT LO-ORDER NIBBLE.
 02FC 0F             476          RRC                         ; ROTATE HON INTO LON.
 02FD 0F             477          RRC
 02FE 0F             478          RRC
 02FF 0F             479          RRC
 0300 C630           480          ADI      30H                ; CONVERT TO ASCII.
 0302 320000    E    481          STA      ALPHA
 0305 CD0000    E    482          CALL     DELAY
 0308 3E3D           483          MVI      A,       3DH      ; SEND "=" TO ALPHA DISPLAY.
 030A 320000    E    484          STA      ALPHA
 030D CD0000    E    485          CALL     DELAY
```

```
LOC  OBJ         LINE        SOURCE STATEMENT

0310 3E3F                 MVI     A,      3FH     ; SEND "?".
0312 320000    E          STA     ALPHA
0315 CD0000    E          CALL    DELAY
0318 C9                   RET
                     ;
                     ;        MESSAGE TABLE FOLLOWS:
                     ;
0319 09              IRVTAB: DB   09H     ; I
031A 0E                   DB      0EH     ; N
031B 14                   DB      14H     ; T
031C 05                   DB      05H     ; E
031D 12                   DB      12H     ; R
031E 16                   DR      16H     ; V
031F 01                   DB      01H     ; A
0320 0C                   DB      0CH     ; L
0321 20                   DB      20H     ; SPACE
                     ;
                     ;*****************************************************************
                     ;
                     ;        THIS ROUTINE CONVERTS A SINGLE BYTE BINARY NUMBER INTO TWO
                     ;        4-BIT BCD VALUES.
                     ;
                     ;        A REG: CONTAINS BINARY NUMBER TO BE CONVERTED.
                     ;        D REG: RETURNS WITH BCD TENS PLACE IN ASCII.
                     ;        C REG: RETURNS WITH BCD ONES PLACE IN ASCII.
                     ;
                     ;*****************************************************************
                     ;
0322 1630            BINASC: MVI  D,      30H     ; LOAD D WITH ASCII ZERO.
0324 C601                 ADI     01H             ; OFF-SET NUMBER TO BE CONVERTED BY ONE
0326 060A            BEGIN:  MVI  B,      0AH     ; LOAD B WITH LOOP COUNTER.
0328 3D              TENCNT: DCR  A               ; SUBTRACT ONE FROM A REG.
0329 CA3403    C          JZ      ONECNT          ; IF A=0 JMP TO ONE'S PLACE.
032C 05                   DCR     B               ; DECREMENT LOOP COUNTER.
032D C22803    C          JNZ     TENCNT          ; DO NOT LEAVE LOOP UNTIL CYCLED 10 TIMES.
0330 14                   INR     D               ; IF THRU TEN TIMES, INCREMENT 10'S COUNTER.
0331 C32603    C          JMP     BEGIN           ; GO AND CYCLE AGAIN.
0334 3E0A            ONECNT: MVI  A,      0AH     ; DETERMINE HOW MANY ONE'S REMAIN.
0336 90                   SUB     B
0337 C630                 ADI     30H             ; CONVERT ONE'S TO ASCII.
0339 4F                   MOV     C,      A       ; STORE RESULT IN C REG.
033A C9                   RET
                     ;
                     ;*****************************************************************
                     ;
                     ;        THIS ROUTINE TAKES THE CURRENT VALUE OF HI-DEB AND DISPLAYS
                     ;        IT ON THE ALPHA DISPLAY IN THE FORMAT:
                     ;
                     ;        " RATE [HI-DEB] = ? "
                     ;
                     ;*****************************************************************
                     ;
033B 3EE1            RATNUM: MVI  A,      0E1H    ; BLANK ALPHA DISPLAY.
033D 320000    E          STA     ALPHA
```

```
LOC  OBJ             SOURCE STATEMENT

0340 CD0000   E             CALL    DELAY
0343 216D03   C             LXI     H,      RATTAB  ; START ADDRESS OF "RATE"
0346 0608                   MVI     B,      08H     ; LOAD TEXT COUNTER.
0348 CD0000   E             CALL    DWRITE          ; WRITE TO DISPLAY.
034B 3A0000   D             LDA     DEB             ; GET I/R COUNT.
034E E6F0                   ANI     0F0H            ; MASK OUT PROCESS COUNT (LOW).
0350 0F                     RRC                     ; ROTATE HOW INTO LOW POSITION.
0351 0F                     RRC
0352 0F                     RRC
0353 0F                     RRC
0354 C630                   ADI     30H             ; CONVERT TO ASCII.
0356 320000   E             STA     ALPHA
0359 CD0000   E             CALL    DELAY
035C 3E3D                   MVI     A,      3DH     ; SEND "=" TO ALPHA DISPLAY.
035E 320000   E             STA     ALPHA
0361 CD0000   E             CALL    DELAY
0364 3E3F                   MVI     A,      3FH     ; SEND "?"
0366 320000   E             STA     ALPHA
0369 CD0000   E             CALL    DELAY
036C C9                     RET
                     ;
                     ;      MESSAGE TABLE FOLLOWS:
                     ;
036D 20              RATTAB: DB     20H     ; SPACE
036E 20                      DB     20H     ; SPACE
036F 12                      DB     12H     ; R
0370 01                      DB     01H     ; A
0371 14                      DB     14H     ; T
0372 05                      DB     05H     ; E
0373 20                      DB     20H     ; SPACE
                     ;
                     ;*************************************************************************
                     ;
                     ;      THIS DELAY ROUTINE GIVES ~5 SECOND PAUSE WHEN CALLED.
                     ;
                     ;*************************************************************************
                     ;
0374 3E10            LDELAY: MVI    A,      10H
0376 16FF            LOOOP3: MVI    D,      0FFH
0378 1EFF            LOOOP2: MVI    E,      0FFH
037A 1D              LOOOP1: DCR    E
037B C27A03   C              JNZ    LOOOP1
037E 15                      DCR    D
037F C27803   C              JNZ    LOOOP2
0382 3D                      DCR    A
0383 C27603   C              JNZ    LOOOP3
0386 C9                      RET
                     ;
                     ;      MESSAGE TABLES FOLLOW:
                     ;
0387 0D              MANMOD: DB     0DH     ; M
0388 01                      DB     01H     ; A
0389 0E                      DB     0EH     ; N
038A 15                      DB     15H     ; U
```

```
 LOC  OBJ        LINE        SOURCE STATEMENT

 038B 01          594         DB       01H     ; A
 038C 0C          595         DB       0CH     ; L
 038D 20          596         DB       20H     ; SPACE
 038E 0D          597         DB       0DH     ; M
 038F 0F          598         DB       0FH     ; O
 0390 04          599         DB       04H     ; D
 0391 05          600         DB       05H     ; E
 0392 3F          601         DB       3FH     ; ?
 0393 20          602 PNTMAN: DB       20H     ; SPACES
 0394 20          603         DB       20H
 0395 20          604         DB       20H
 0396 20          605         DB       20H
 0397 20          606         DB       20H
 0398 20          607         DB       20H
 0399 20          608         DB       20H
 039A 2A          609         DB       2AH     ; *
 039B 2A          610         DB       2AH     ; *
 039C 20          611         DB       20H     ; SPACE
 039D 4D          612         DB       4DH     ; M
 039E 61          613         DB       61H     ; A
 039F 6E          614         DB       6EH     ; N
 03A0 75          615         DB       75H     ; U
 03A1 61          616         DB       61H     ; A
 03A2 6C          617         DB       6CH     ; L
 03A3 20          618         DB       20H     ; SPACE
 03A4 4D          619         DB       4DH     ; M
 03A5 6F          620         DB       6FH     ; O
 03A6 64          621         DB       64H     ; D
 03A7 65          622         DB       65H     ; E
 03A8 20          623         DB       20H     ; SPACE
 03A9 53          624         DB       53H     ; S
 03AA 65          625         DB       65H     ; E
 03AB 6C          626         DB       6CH     ; L
 03AC 65          627         DB       65H     ; E
 03AD 63          628         DB       63H     ; C
 03AE 74          629         DB       74H     ; T
 03AF 65          630         DB       65H     ; E
 03B0 64          631         DB       64H     ; D
 03B1 20          632         DB       20H     ; SPACE
 03B2 2A          633         DB       2AH     ; *
 03B3 2A          634         DB       2AH     ; *
                  635 ;
                  636         DSEG
                  637 ;
 0000             638 DEB:    DS       1H      ; 1 BYTE OF RAM FOR DATA ENTRY BYTE.
 0001             639 ITAB:   DS       1H      ; 1 BYTE OF RAM FOR INTERVAL TABULATION.
 0002             640 STAB:   DS       1H      ; 1 BYTE OF RAM FOR SCAN TABULATION.
 0003             641 PLBYTE: DS       4H      ; 4 BYTE OF RAM FOR PROCESS LENGTH BYTES.
 0007             642 IRCNT:  DS       4H      ; 4 BYTE OF RAM FOR # OF I/R ENTRIES PER PROCESS.
 000B             643 IRBRAM: DS       1FH     ; 30 BYTES OF RAM FOR I/R BYTES
 002A             644 MANFLG: DS       1H      ; MANUAL FLAG BYTE.
 002B             645 STABCT: DS       04H     ; 0=0,1=01 SCN TOTAL,2=01+02 SCN TOT,3=TOTAL SCANS.
                  646 ;
                  647         END
```

```
  LOC  OBJ         LINE        SOURCE STATEMENT
```



```
PUBLIC SYMBOLS
BINASC C 0322   DATAIN C 0000   DEB    D 0000   IRBRAM D 000B   IRCNT  D 0007   LDELAY C 0374   MANFLG D 002A
MANMOD C 0387   PLBYTE D 0003   STABCT D 002B

EXTERNAL SYMBOLS
ALPHA  E 0000   DELAY  E 0000   DEVNUM E 0000   DWRITE E 0000   GODEV  E 0000   KDSPY2 E 0000   KDSPY3 E 0000
PNTNUM E 0000   PSEND  E 0000   PWRITE E 0000   RPA2   E 0000   SUM2   E 0000   SUM3   E 0000

USER SYMBOLS
ALPHA  E 0000   BEGIN  C 0326   BINASC C 0322   D1TAB  C 02BA   D2TAB  C 02CE   DATAIN C 0000   DEB    D 0000
DELAY  E 0000   DEVNUM E 0000   DWRITE E 0000   EDBLNK C 0105   FRONT  C 0053   GODEV  E 0000   HERE   C 015C
INVLID C 0130   IRBRAM D 000B   IRCNT  D 0007   IRVNUM C 02E7   IRVTAB C 0319   ITAB   D 0001   KDSPY2 E 0000
KDSPY3 E 0000   LDELAY C 0374   LESS   C 011B   LOOOP1 C 037A   LOOOP2 C 0378   LOOOP3 C 0376   MANFLG D 002A
MANMOD C 0387   MANTST C 01C8   MINUTE C 02C6   MORE   C 015D   NEXT   C 01E0   NOMORE C 0193   OMT    C 0074
OMTA   C 00BD   OMTYA  C 011E   ONECNT C 0334   OUTINT C 020A   PASS   C 008A   PASS2  C 0166   PASS3  C 0173
PASSA  C 013B   PFULL  C 01FE   PLBYTE D 0003   PNTIR  C 0222   PNTMAN C 0393   PNTNUM E 0000   PRINT  C 0185
PSEND  E 0000   PWRITE E 0000   RAMCNT C 01D3   RATBIG C 01B2   RATEIN C 00A3   RATNUM C 033B   RATTAB C 036D
RPA2   E 0000   SCNMIN C 02DA   SCNOUT C 01A2   SMORE  C 016E   STAB   D 0002   STABCT D 002B   STORE  C 01FA
SUM2   E 0000   SUM3   E 0000   TENCNT C 0328   TOOBIG C 0216

ASSEMBLY COMPLETE,   NO ERRORS
```

```
LOC  OBJ          LINE        SOURCE STATEMENT

                        ;**************************************************************
                        ;
                        ;       THIS PROGRAM MODULE CONTAINS MOST OF THE IMPORTANT
                        ;       SUBROUTINES USED BY THE IN-PROCESS IR DENSITOMETER.
                        ;       EACH SUBROUTINE IS PROCEEDED BY A BRIEF DESCRIPTION
                        ;       OF WHAT ITS FUNCTION IS AND THE PARAMETERS THAT MUST
                        ;       BE PASSED TO IT.
                        ;
                        ;**************************************************************
                        ;
                        ;
                                NAME    SUBPAK
                        ;
                                PUBLIC  KDSPY2,KDSPY3,KSTOR1,KSTOR2,KSTOR3,PNTNUM,DEVNUM
                                PUBLIC  PWRITE,SUM2,SUM3,LOOKUP,FIFOCR
                        ;
                                EXTRN   COMM1,DATA1,COMM2,DATA2,PSEND,DELAY,ALPHA,DWRITE
                                EXTRN   DEB,POS1,POS2,CLEARA,CLEARB,RPOS1
                        ;
                                CSEG
                        ;
                        ;**********************************************************************
                        ;
                        ;       THIS SUBROUTINE WILL ALLOW FOR THE ENTRY OF TWO NUMERIC DIGITS
                        ;       FROM THE CONTROL PANEL KEYBOARD. MISTAKES MADE ON THE KEYBOARD
                        ;       ARE CLEARED USING THE "CE" OR CLEAR ENTRY KEY. WHEN THE CORRECT
                        ;       DIGITS SELECTED BY THE USER ARE ON THE DISPLAY, THE "E" OR ENTER
                        ;       KEY WILL INPUT THE SELECTIONS TO THE COMPUTER. KEY ENTRIES ARE
                        ;       RIGHT ENTRY ONLY AND ARE RETURNED TO THE COMPUTER IN MEMORY
                        ;       LOCATIONS KSTOR1 AND KSTOR2.
                        ;
                        ;**********************************************************************
                        ;
0000 CD0202     C       KDSPY2: CALL    FIFOCR              ; EMPTY THE FIFO.
0003 0600                       MVI     B,      00H         ; SET DIGIT COUNTER TO 0.
0005 78                         MOV     A,      B           ; ZERO A REGISTER.
0006 320000     D               STA     KSTOR1
0009 320100     D               STA     KSTOR2              ; ZERO TEMP. KEY ENTRY REGISTERS.
000C 210000     E               LXI     H,      COMM1       ; WRITE ZEROS TO POS. 3 & 4 ON CONTROL DSP.
000F 3A0000     E               LDA     CLEARA              ; CLEAR DISPLAY RAM ACCORDING TO CLEAR CODE.
0012 77                         MOV     M,      A
0013 CD0000     E               CALL    DELAY
0016 3A0000     E               LDA     POS2
0019 77                         MOV     M,      A
001A CD0000     E               CALL    DELAY
001D 210000     E               LXI     H,      DATA1       ; 8279 DATA ADDRESS.
0020 3E0C                       MVI     A,      0CH         ; LOAD DIGIT CODE FOR ZERO (0).
0022 77                         MOV     M,      A
0023 77                         MOV     M,      A           ; WRITE 2 ZEROS TO DISPLAY.
0024 210000     E       KLOOK:  LXI     H,      COMM2       ; STATUS WORD ADDRESS OF EXP. 8279.
0027 7E                         MOV     A,      M           ; PUT IT INTO A REG.
0028 E603                       ANI     03H                 ; MASK OUT 5 HI-ORDER BITS.
002A FE01                       CPI     01H                 ; IF SOMETHING IN FIFO, ZERO WILL SET.
```

```
  LOC  OBJ          LINE        SOURCE STATEMENT

  002C C22400   C     54        JNZ     KLOOK              ; IF NOT, KEEP LOOKING.
  002F 3E40           55        MVI     A,      40H        ; SET FOR FIFO READ.
  0031 77             56        MOV     M,      A          ; SELECT FIFO AS READ SOURCE.
  0032 210000   E     57        LXI     H,      DATA2      ; DATA ADDRESS OF EXPANSION 8279.
  0035 7E             58        MOV     A,      M          ; PUT FIFO CONTENTS INTO A REG.
  0036 E60F           59        ANI     0FH                ; MASK OUT HI-ORDER NIBBLE.
  0038 FE00           60        CPI     00H                ; IF CE KEY, ZERO FLAG WILL SET.
  003A CA0000   C     61        JZ      KDSPY2             ; START OVER IF CE KEY PUSHED.
  003D FE0F           62        CPI     0FH                ; IF ENTER KEY, ZERO WILL SET.
  003F CAA200   C     63        JZ      NOBLNK             ; BEFORE RETURN, STOP ALPHA FROM BLINKING.
  0042 21F301   C     64        LXI     H,      NUMTAB     ; GET DECIMAL KEY VALUE.
  0045 85             65        ADD     L                  ; ADD KEY VALUE TO L REGISTER.
  0046 6F             66        MOV     L,      A          ; HL NOW POINTS TO ABSOLUTE KEY VALUE.
  0047 7E             67        MOV     A,      M          ; GET ACTUAL DECIMAL KEY VALUE.
  0048 FEFF           68        CPI     0FFH               ; IF ERROR KEY, ZERO FLAG WILL SET.
  004A CA2400   C     69        JZ      KLOOK              ; IF ERROR, GO AND READ KEYBOARD AGAIN.
  004D 04             70        INR     B                  ; INCREMENT DIGIT COUNTER.
  004E 4F             71        MOV     C,      A          ; STORE A IN C REG.
  004F 3E01           72        MVI     A,      01H        ; PREPARE TO TEST DIGIT COUNTER.
  0051 B8             73        CMP     B                  ; IF DIGIT COUNTER=01, ZERO FLAG WILL SET.
  0052 CA5E00   C     74        JZ      STOR1              ; IF 01, GO TO KSTOR1 ROUTINE.
  0055 3E02           75        MVI     A,      02H        ; TEST TO SEEE IF = TO 02.
  0057 B8             76        CMP     B
  0058 CA7300   C     77        JZ      STOR2              ; IF ZERO SETS, GO TO KSTOR2 ROUTINE.
  005B C32400   C     78        JMP     KLOOK              ; MUST BE 3RD KEY ENTRY. NOT ALLOWED!!!!
  005E 79             79 STOR1: MOV     A,      C          ; RETRIVE A ( DECIMAL KEY VALUE ).
  005F 320000   D     80        STA     KSTOR1
  0062 CDE201   C     81        CALL    LOOKUP             ; NOW GET VALUE FOR DISPLAY, RET IN C REG.
  0065 210000   E     82        LXI     H,      COMM1
  0068 3A0000   E     83        LDA     POS1               ; DISPLAY POS. 1 NON-AI.
  006B 77             84        MOV     M,      A
  006C 210000   E     85        LXI     H,      DATA1
  006F 71             86        MOV     M,      C          ; SEND CHARACTER TO DISPLAY POS. 1.
  0070 C32400   C     87        JMP     KLOOK              ; GO LOOK FOR NEXT KEY ENTRY.
  0073 79             88 STOR2: MOV     A,      C          ; RETRIVE A.
  0074 320100   D     89        STA     KSTOR2             ; STORE DECIMAL KEY VALUE IN KSTOR2.
  0077 CDE201   C     90        CALL    LOOKUP             ; GET DISPLAY CHARACTER.
  007A 210000   E     91        LXI     H,      COMM1
  007D 3A0000   E     92        LDA     RPOS1              ; READ DISPLAY RAM POS. 1
  0080 77             93        MOV     M,      A
  0081 210000   E     94        LXI     H,      DATA1
  0084 56             95        MOV     D,      M          ; READ VALUE INTO D REG.
  0085 210000   E     96        LXI     H,      COMM1
  0088 3A0000   E     97        LDA     POS2               ; PREPARE TO WRITE TO POS. 2 (AI).
  008B 77             98        MOV     M,      A
  008C 210000   E     99        LXI     H,      DATA1
  008F 72            100        MOV     M,      D          ; WRITE POS. 1 TO POS. 2.
  0090 71            101        MOV     M,      C          ; NOW WRITE 2ND KEY ENTRY TO POS. 1
  0091 3A0100   D    102        LDA     KSTOR2
  0094 57            103        MOV     D,      A
  0095 3A0000   D    104        LDA     KSTOR1
  0098 320100   D    105        STA     KSTOR2             ; REVERSE CONTENTS OF KSTOR 1 & 2.
  009B 7A            106        MOV     A,      D
  009C 320000   D    107        STA     KSTOR1
```

```
LOC  OBJ          LINE        SOURCE STATEMENT

009F C32400   C   108         JMP    KLOOK         ; GO LOOK FOR E OR CE KEY ENTRY.
00A2 210000   E   109 NOBLNK: LXI    H,     COMM1
00A5 3A0000   E   110         LDA    CLEARB        ; BLANK DISPLAY PER CODE IN CLRCOD.
00A8 77           111         MOV    M,     A
00A9 3EC3         112         MVI    A,     0C3H   ; CODE FOR NO-BLINK
00AB 320000   E   113         STA    ALPHA         ; CONTROL WORD.
00AE CD0000   E   114         CALL   DELAY
00B1 3A0000   D   115         LDA    KSTOR1        ; WANT TO GET A SINGLE BYTE # FROM KSTOR1,2.
00B4 2E00         116         MVI    L,     00H    ; ZERO L AS L WILL CONTAIN RUNNING SUM.
00B6 0E01         117         MVI    C,     01H    ; C BECOMES 1'S FACTOR.
00B8 09           118 ONES2:  DAD    B             ; ADD BC TO HL.
00B9 3D           119         DCR    A             ; DECREMENT ONES'S COUNTER.
00BA FE00         120         CPI    00H           ; IF COUNTER = 0, ZERO WILL SET.
00BC C2B800   C   121         JNZ    ONES2         ; IF NO ZERO, KEEP ADDING ONES.
00BF 3A0100   D   122         LDA    KSTOR2        ; NOW DO IT FOR 10'S PLACE.
00C2 0E0A         123         MVI    C,     0AH    ; C IS NOW 10'S FACTOR.
00C4 09           124 TENS2:  DAD    B             ; ADD BC TO HL.
00C5 3D           125         DCR    A             ; DECREMENT 10'S COUNTER.
00C6 FE00         126         CPI    00H
00C8 C2C400   C   127         JNZ    TENS2
00CB 7D           128         MOV    A,     L      ; PLACE RUNNING SUM INTO A REG.
00CC 320300   D   129         STA    SUM2          ; STORE RUNNING SUM AT SUM2.
00CF C9           130         RET                  ; RETURN TO MAIN PROGRAM.
                  131 ;
                  132 ;*************************************************************************
                  133 ;
                  134 ;       THIS IS KDSPY3. IT IS LIKE KDSPY2 EXCEPT THAT 3 KEY ENTRIES
                  135 ;       ARE ALLOWED RATHER THAN ONLY TWO.
                  136 ;
                  137 ;*************************************************************************
                  138 ;
00D0 CD0202   C   139 KDSPY3: CALL   FIFOCR        ; EMPTY THE FIFO.
00D3 0600         140         MVI    B,     00H    ; SET DIGIT COUNTER TO 0.
00D5 78           141         MOV    A,     B      ; ZERO A REGISTER.
00D6 320000   D   142         STA    KSTOR1
00D9 320100   D   143         STA    KSTOR2
00DC 320200   D   144         STA    KSTOR3        ; ZERO TEMP. KEY ENTRY REGISTERS.
00DF 210000   E   145         LXI    H,     COMM1  ; WRITE ZEROS TO POS. 2 & 3 & 4 ON CONTROL DSP.
00E2 36DF         146         MVI    M,     0DFH
00E4 CD0000   E   147         CALL   DELAY
00E7 3692         148         MVI    M,     92H
00E9 210000   E   149         LXI    H,     DATA1  ; 8279 DATA ADDRESS.
00EC 3E0C         150         MVI    A,     0CH    ; LOAD DIGIT CODE FOR ZERO (0).
00EE 77           151         MOV    M,     A
00EF 77           152         MOV    M,     A
00F0 77           153         MOV    M,     A      ; WRITE 3 ZEROS TO DISPLAY.
00F1 210000   E   154 KLOOK3: LXI    H,     COMM2  ; STATUS WORD ADDRESS OF EXP. 8279.
00F4 7E           155         MOV    A,     M      ; PUT IT INTO A REG.
00F5 E603         156         ANI    03H           ; MASK OUT 5 HI-ORDER BITS.
00F7 FE01         157         CPI    01H           ; IF SOMETHING IN FIFO, ZERO WILL SET.
00F9 C2F100   C   158         JNZ    KLOOK3        ; IF NOT, KEEP LOOKING.
00FC 3E40         159         MVI    A,     40H    ; SET FOR FIFO READ.
00FE 77           160         MOV    M,     A      ; SELECT FIFO AS READ SOURCE.
00FF 210000   E   161         LXI    H,     DATA2  ; DATA ADDRESS OF EXPANSION 8279.
```

```
 LOC  OBJ         LINE        SOURCE STATEMENT

 0102 7E           162          MOV    A,     M      ; PUT FIFO CONTENTS INTO A REG.
 0103 E60F         163          ANI    0FH           ; MASK OUT HI-ORDER NIBBLE.
 0105 FE00         164          CPI    00H           ; IF CE KEY, ZERO FLAG WILL SET.
 0107 CAD000   C   165          JZ     KDSPY3        ; START OVER IF CE KEY PUSHED.
 010A FE0F         166          CPI    0FH           ; IF ENTER KEY, ZERO WILL SET.
 010C CAAA01   C   167          JZ     NOBLN3        ; BEFORE RETURN, STOP ALPHA FROM BLINKING.
 010F 21F301   C   168          LXI    H,     NUMTAB ; GET DECIMAL KEY VALUE.
 0112 85           169          ADD    L             ; ADD KEY VALUE TO L REGISTER.
 0113 6F           170          MOV    L,     A      ; HL NOW POINTS TO ABSOLUTE KEY VALUE.
 0114 7E           171          MOV    A,     M      ; GET ACTUAL DECIMAL KEY VALUE.
 0115 FEFF         172          CPI    0FFH          ; IF ERROR KEY, ZERO FLAG WILL SET.
 0117 CAF100   C   173          JZ     KLOOK3        ; IF ERROR, GO AND READ KEYBOARD AGAIN.
 011A 04           174          INR    B             ; INCREMENT DIGIT COUNTER.
 011B 4F           175          MOV    C,     A      ; STORE A IN C REG.
 011C 3E01         176          MVI    A,     01H    ; PREPARE TO TEST DIGIT COUNTER.
 011E B8           177          CMP    B             ; IF DIGIT COUNTER=01, ZERO FLAG WILL SET.
 011F CA3101   C   178          JZ     STOR13        ; IF 01, GO TO KSTOR1 ROUTINE.
 0122 3E02         179          MVI    A,     02H    ; TEST TO SEEE IF = TO 02.
 0124 B8           180          CMP    B
 0125 CA4401   C   181          JZ     STOR23        ; IF ZERO SETS, GO TO KSTOR2 ROUTINE.
 0128 3E03         182          MVI    A,     03H    ; IS IT 3RD KEY?
 012A B8           183          CMP    B
 012B CA6F01   C   184          JZ     STOR33        ; IF ZERO SETS, GO TO KSTOR3 ROUTINE.
 012E C3F100   C   185          JMP    KLOOK3        ; MUST BE 4TH KEY ENTRY. NOT ALLOWED!!!!
 0131 79           186 STOR13:  MOV    A,     C      ; RETRIVE A ( DECIMAL KEY VALUE ).
 0132 320000   D   187          STA    KSTOR1
 0135 CDE201   C   188          CALL   LOOKUP        ; NOW GET VALUE FOR DISPLAY, RET IN C REG.
 0138 210000   E   189          LXI    H,     COMM1
 013B 3684         190          MVI    M,     84H    ; DISPLAY POS. 1 NON-AI.
 013D 210000   E   191          LXI    H,     DATA1
 0140 71           192          MOV    M,     C      ; SEND CHARACTER TO DISPLAY POS. 1.
 0141 C3F100   C   193          JMP    KLOOK3        ; GO LOOK FOR NEXT KEY ENTRY.
 0144 79           194 STOR23:  MOV    A,     C      ; RETRIVE A.
 0145 320100   D   195          STA    KSTOR2        ; STORE DECIMAL KEY VALUE IN KSTOR2.
 0148 CDE201   C   196          CALL   LOOKUP        ; GET DISPLAY CHARACTER.
 014B 210000   E   197          LXI    H,     COMM1
 014E 3664         198          MVI    M,     64H    ; READ DISPLAY RAM POS. 1
 0150 210000   E   199          LXI    H,     DATA1
 0153 7E           200          MOV    A,     M      ; READ VALUE INTO A REG.
 0154 210000   E   201          LXI    H,     COMM1
 0157 3693         202          MVI    M,     93H    ; PREPARE TO WRITE TO POS. 2 (AI).
 0159 210000   E   203          LXI    H,     DATA1
 015C 77           204          MOV    M,     A      ; WRITE POS. 1 TO POS. 2.
 015D 71           205          MOV    M,     C      ; NOW WRITE 2ND KEY ENTRY TO POS. 1
 015E 3A0100   D   206          LDA    KSTOR2        ; REVERSE KSTOR1 & KSTOR2.
 0161 57           207          MOV    D,     A
 0162 3A0000   D   208          LDA    KSTOR1
 0165 320100   D   209          STA    KSTOR2
 0168 7A           210          MOV    A,     D
 0169 320000   D   211          STA    KSTOR1
 016C C3F100   C   212          JMP    KLOOK3        ; GO LOOK FOR 3RD KEY ENTRY.
 016F 79           213 STOR33:  MOV    A,     C      ; RETRIVE A.
 0170 320200   D   214          STA    KSTOR3        ; STORE DECIMAL KEY VALUE IN KSTOR3.
 0173 CDE201   C   215          CALL   LOOKUP        ; GET DISPLAY CHARACTER.
```

```
LOC  OBJ         LINE        SOURCE STATEMENT

0176 210000   E   216            LXI     H,       COMM1
0179 3663         217            MVI     M,       63H     ; READ DISPLAY RAM POS. 2 (ADDRESS=03H).
017B 210000   E   218            LXI     H,       DATA1
017E 7E           219            MOV     A,       M       ; READ POS.2 VALUE INTO A REG.
017F 210000   E   220            LXI     H,       COMM1
0182 3664         221            MVI     M,       64H     ; READ DISPLAY RAM POS. 1 (ADDRESS=04H).
0184 210000   E   222            LXI     H,       DATA1
0187 56           223            MOV     D,       M       ; READ POS.1 VALUE INTO D REG.
0188 210000   E   224            LXI     H,       COMM1
018B 3692         225            MVI     M,       92H     ; PREPARE TO WRITE TO POS.3 (AI).
018D 210000   E   226            LXI     H,       DATA1
0190 77           227            MOV     M,       A       ; WRITE 1ST KEY ENTRY TO POS.3 (ADDRESS=02H).
0191 72           228            MOV     M,       D       ; WRITE 2ND KEY ENTRY TO POS.2 (ADDRESS=03H).
0192 71           229            MOV     M,       C       ; WRITE 3RD KEY ENTRY TO POS.3 (ADDRESS=04H).
0193 3A0200   D   230            LDA     KSTOR3
0196 57           231            MOV     D,       A
0197 3A0100   D   232            LDA     KSTOR2
019A 320200   D   233            STA     KSTOR3
019D 3A0000   D   234            LDA     KSTOR1
01A0 320100   D   235            STA     KSTOR2
01A3 7A           236            MOV     A,       D
01A4 320000   D   237            STA     KSTOR1           ; SCHUFFLE KSTORs AROUND ABIT.
01A7 C3F100   C   238            JMP     KLOOK3           ; GO LOOK FOR E OR CE KEY ENTRY.
01AA 3EC3         239 NOBLN3:  MVI     A,       0C3H    ; CODE FOR NO-BLINK
01AC 320000   E   240            STA     ALPHA            ; CONTROL WORD.
01AF CD0000   E   241            CALL    DELAY
01B2 3A0000   D   242            LDA     KSTOR1           ; WANT TO GET A SINGLE BYTE # FROM KSTOR1,2,3.
01B5 2E00         243            MVI     L,       00H     ; ZERO L AS L WILL CONTAIN RUNNING SUM.
01B7 0E01         244            MVI     C,       01H     ; C BECOMES 1'S FACTOR.
01B9 09           245 ONES3:   DAD     B                ; ADD BC TO HL.
01BA 3D           246            DCR     A                ; DECREMENT ONES'S COUNTER.
01BB FE00         247            CPI     00H              ; IF COUNTER = 0, ZERO WILL SET.
01BD C2B901   C   248            JNZ     ONES3            ; IF NO ZERO, KEEP ADDING ONES.
01C0 3A0100   D   249            LDA     KSTOR2           ; NOW DO IT FOR 10'S PLACE.
01C3 0E0A         250            MVI     C,       0AH     ; C IS NOW 10'S FACTOR.
01C5 09           251 TENS3:   DAD     B                ; ADD BC TO HL.
01C6 3D           252            DCR     A                ; DECREMENT 10'S COUNTER.
01C7 FE00         253            CPI     00
01C9 C2C501   C   254            JNZ     TENS3
01CC 3A0200   D   255            LDA     KSTOR3           ; NOW DO IT FOR HUNDREDS PLACE.
01CF 0E64         256            MVI     C,       64H     ; C IS NOW 100'S FACTOR.
01D1 09           257 HUNS3:   DAD     B
01D2 3D           258            DCR     A
01D3 FE00         259            CPI     00
01D5 C2D101   C   260            JNZ     HUNS3
01D8 7D           261            MOV     A,       L       ; PLACE RUNNING SUM INTO A REG.
01D9 320400   D   262            STA     SUM3             ; STORE RUNNING SUM AT SUM2.
01DC 210000   E   263            LXI     H,       COMM1
01DF 36DF         264            MVI     M,       0DFH
01E1 C9           265            RET                      ; RETURN TO CALLING PROGRAM.
                  266 ;
                  267 ;          SUBROUTINES FOLLOW:
                  268 ;
01E2 21E901   C   269 LOOKUP:  LXI     H,       DTABLE  ; STARTING ADDRESS OF DISPLAY TABLE.
```

```
 LOC  OBJ                SOURCE STATEMENT

 01E5 85                         ADD     L                    ; ADD KEY VALUE (0-9) TO LOB OF DTABLE.
 01E6 6F                         MOV     L,      A            ; MOVE RESULT TO L REGISTER.
 01E7 4E                         MOV     C,      M            ; PUT DISPLAY RESULT INTO C REGISTER.
 01E8 C9                         RET
                        ;
                        ;        LOOK-UP TABLES USED IN FINDING KEY VALUES FOLLOW:
                        ;
 01E9 0C                DTABLE:  DB      0CH     ; 0     FOR CONTROL DISPLAY.
 01EA 9F                         DB      9FH     ; 1
 01EB 4A                         DB      4AH     ; 2
 01EC 0B                         DB      0BH     ; 3
 01ED 99                         DB      99H     ; 4
 01EE 29                         DB      29H     ; 5
 01EF 28                         DB      28H     ; 6
 01F0 0F                         DB      0FH     ; 7
 01F1 08                         DB      08H     ; 8
 01F2 09                         DB      09H     ; 9
                        ;
 01F3 FF                NUMTAB:  DB      0FFH    ; FF IS ERROR CODE FOR INVALID KEY ENTRY.
 01F4 03                         DB      03H
 01F5 06                         DB      06H
 01F6 09                         DB      09H
 01F7 00                         DB      00H
 01F8 02                         DB      02H
 01F9 05                         DB      05H
 01FA 08                         DB      08H
 01FB FF                         DB      0FFH    ; ERROR
 01FC 01                         DB      01H
 01FD 04                         DB      04H
 01FE 07                         DB      07H
 01FF FF                         DB      0FFH    ; ERROR
 0200 FF                         DB      0FFH    ; ERROR
 0201 FF                         DB      0FFH    ; ERROR
                        ;
                        ;*****************************************************************
                        ;        THIS SUBROUTINE EMPTIES THE KEYBOARD FIFO.
                        ;*****************************************************************
                        ;
 0202 210000   E        FIFOCR:  LXI     H,      COMM2   ; SET FOR FIFO READ AUTO-INCREMENT.
 0205 3641                       MVI     M,      41H
 0207 210000   E        EMPTY:   LXI     H,      COMM2
 020A 7E                         MOV     A,      M       ; GET FIFO STATUS WORD.
 020B E603                       ANI     03H             ; MASK OUT 5 HI-ORDER BITS.
 020D FE00                       CPI     00H
 020F C8                         RZ                      ; IF ZERO SETS, THEN FIFO EMPTY SO RETURN.
 0210 210000   E                 LXI     H,      DATA2
 0213 7E                         MOV     A,      M
 0214 C30702   C                 JMP     EMPTY
                        ;
                                 DSEG
                        ;
 0000                   KSTOR1:  DS      1
 0001                   KSTOR2:  DS      1
 0002                   KSTOR3:  DS      1
```

```
LOC  OBJ         LINE        SOURCE STATEMENT

0003              324 SUM2:   DS      1
0004              325 SUM3:   DS      1
                  326 ;
                  327         CSEG
                  328 ;
                  329 ;**********************************************************************
                  330 ;
                  331 ;       THIS SUBROUTINE WRITES A MESSAGE TO THE LINE PRINTER.
                  332 ;       PWRITE (PRINTER WRITE) REQUIRES THE FOLLOWING INFORMATION.
                  333 ;               C REG: CONTAINS THE LENGTH OF THE TEXT STRING TO
                  334 ;               BE WRITTEN TO THE PRINTER.
                  335 ;               HL REG: CONTAINS THE STARTING ADDRESS OF THE TEXT
                  336 ;               STRING.
                  337 ;       THIS ROUTINE CALLS PSEND.
                  338 ;
                  339 ;:*********************************************************************
                  340 ;
0217 0D           341 PWRITE: DCR     C                 ; DECREMENT CHARACTER COUNTER.
0218 3E00         342         MVI     A,      00H       ; PREPARE TO TEST COUNTER.
021A B9           343         CMP     C                 ; IF C=0 ZERO FLAG WILL SET.
021B C8           344         RZ                        ; IF NO MORE TO SEND, THEN RETURN.
021C 7E           345         MOV     A,      M         ; PUT CHARACTER POINTED TO BY HL INTO A.
021D CD0000   E   346         CALL    PSEND             ; SEND IT TO PRINTER.
0220 23           347         INX     H                 ; INCREMENT TEXT POINTER.
0221 C31702   C   348         JMP     PWRITE
                  349 ;
                  350 ;**********************************************************************
                  351 ;
                  352 ;       THIS SUBROUTINE TAKES THE LO-ORDER NIBBLE STORED AT DEB
                  353 ;       ( FOR DATA ENTRY BYTE) AND DISPLAYS IT IN THE FORMAT OF
                  354 ;       " PROCESS (LO-DEB) = ? " ON THE ALPHA DISPLAY.
                  355 ;
                  356 ;**********************************************************************
                  357 ;
0224 3EE1         358 DEVNUM: MVI     A,      0E1H      ; LOAD BLANK CODE.
0226 320000   E   359         STA     ALPHA
0229 CD0000   E   360         CALL    DELAY
022C 215202   C   361         LXI     H,      DEVTAB    ; LOAD STARTING ADDRESS OF MESSAGE.
022F 0609         362         MVI     B,      09H       ; LOAD TEXT COUNTER.
0231 CD0000   E   363         CALL    DWRITE            ; WRITE MESSAGE ON ALPHA DISPLAY.
0234 3A0000   E   364         LDA     DEB               ; LOAD DATA ENTRY BYTE (DEB).
0237 E60F         365         ANI     0FH               ; MASK TO GET PROCESS ENTRY COUNTER.
0239 C630         366         ADI     30H               ; CONVERT TO ASCII.
023B 320000   E   367         STA     ALPHA             ; SEND TO DISPLAY.
023E CD0000   E   368         CALL    DELAY
0241 3E3D         369         MVI     A,      3DH       ; SEND "=" TO ALPHA DISPLAY.
0243 320000   E   370         STA     ALPHA
0246 CD0000   E   371         CALL    DELAY
0249 3E3F         372         MVI     A,      3FH       ; SEND "?" TO DISPLAY.
024B 320000   E   373         STA     ALPHA
024E CD0000   E   374         CALL    DELAY
0251 C9           375         RET                       ; RETURN TO CALLING PROGRAM.
                  376 ;
                  377 ;       MESSAGE TABLE FOLLOWS:
```

```
 LOC  OBJ          LINE       SOURCE STATEMENT

                      ;
 0252 10              DEVTAB: DB      10H      ; P
 0253 12                      DB      12H      ; R
 0254 0F                      DB      0FH      ; O
 0255 03                      DB      03H      ; C
 0256 05                      DB      05H      ; E
 0257 13                      DB      13H      ; S
 0258 13                      DB      13H      ; S
 0259 20                      DB      20H      ; SPACE
                      ;
                      ;**********************************************************************
                      ;
                      ;       THIS SUBROUTINE TAKES THE VALUE OF THE LO-ORDER NIBBLE OF DEB
                      ;       AND THE CURRENT CONTENTS OF KSTOR3,2,1 AND PRINTS THEM ON THE
                      ;       LINE PRINTER. THE MESSAGE FORMAT IS:
                      ;               " PROCESS [LO-DEB] = [KSTOR3,2,1] MINUTES "
                      ;       CALLS PWRITE AND PSEND.
                      ;
                      ;**********************************************************************
                      ;
 025A CDBE02    C     PNTNUM: CALL    STAR              ; PRINT A FULL ROW OF " ****** "
 025D 21CF02    C             LXI     H,       PENTRY   ; STARTING ADDRESS OF MESSAGE.
 0260 0E11                    MVI     C,       11H      ; LOAD MESSAGE LENGTH.
 0262 CD1702    C             CALL    PWRITE            ; WRITE MESSAGE TO PRINTER.
 0265 3A0000    E             LDA     DEB
 0268 E60F                    ANI     0FH               ; MASK TO GET PROCESS ENTRY COUNTER.
 026A C630                    ADI     30H               ; CONVERT IT TO ASCII.
 026C CD0000    E             CALL    PSEND             ; SEND IT TO PRINTER.
 026F 3E20                    MVI     A,       20H      ; SEND BLANK.
 0271 CD0000    E             CALL    PSEND
 0274 3E3D                    MVI     A,       3DH      ; SEND "=" TO PRINTER.
 0276 CD0000    E             CALL    PSEND
 0279 3E20                    MVI     A,       20H      ; SEND ANOTHER BLANK.
 027B CD0000    E             CALL    PSEND
 027E 3A0200    D             LDA     KSTOR3            ; NOW SENDS ACTUAL VALUES TO PRINTER.
 0281 FE00                    CPI     00H               ; USE LEADING ZERO BLANKING.
 0283 C28E02    C             JNZ     NOBLK1
 0286 3E20                    MVI     A,       20H
 0288 CD0000    E             CALL    PSEND
 028B C39302    C             JMP     DIG2
 028E C630            NOBLK1: ADI     30H               ; HUNDREDS NOT EQUAL TO 0. CONVERT ASCII.
 0290 CD0000    E             CALL    PSEND
 0293 3A0100    D     DIG2:   LDA     KSTOR2            ; GET 10'S PLACE.
 0296 C630                    ADI     30H               ; CONVERT TO ASCII.
 0298 CD0000    E             CALL    PSEND
 029B 3A0000    D             LDA     KSTOR1            ; GET 1'S PLACE.
 029E C630                    ADI     30H               ; CONVERT
 02A0 CD0000    E             CALL    PSEND
 02A3 21DF02    C             LXI     H,       PMIN     ; END BY SENDING "MINUTES" TO PRINTER.
 02A6 0E09                    MVI     C,       09H      ; LOAD CHARACTER COUNT.
 02A8 CD1702    C             CALL    PWRITE
 02AB 3E17                    MVI     A,       17H      ; NOW PRINT PRINTER BUFFER CONTENTS.
 02AD CD0000    E             CALL    PSEND
 02B0 CDBE02    C             CALL    STAR              ; UNDERLINE MESSAGE WITH " ****** "
```

```
 LOC  OBJ         LINE        SOURCE STATEMENT

 02B3 3E17         432          MVI     A,      17H     ; NOW SPACE 2 BLANK LINES.
 02B5 CD0000   E   433          CALL    PSEND
 02B8 3E17         434          MVI     A,      17H
 02BA CD0000   E   435          CALL    PSEND
 02BD C9           436          RET                     ; RETURN TO CALLING PROGRAM.
                   437 ;
                   438 ;        ROUTINE TO GENERATE ONE FULL ROW OF " ***** "
                   439 ;
 02BE 0E27         440 STAR:    MVI     C,      27H     ; LOAD COLUMN COUNT WITH 39 COUNTS.
 02C0 3E2A         441 UNMAS:   MVI     A,      2AH     ; LOAD A WITH ASCII FOR " * ".
 02C2 CD0000   E   442          CALL    PSEND           ; SEND IT TO PRINTER.
 02C5 0D           443          DCR     C
 02C6 C2C002   C   444          JNZ     UNMAS
 02C9 3E17         445          MVI     A,      17H     ; START TO PRINT COMMAND.
 02CB CD0000   E   446          CALL    PSEND
 02CE C9           447          RET
                   448 ;
                   449 ;        MESSAGE TABLES FOLLOW:
                   450 ;
 02CF 20           451 PENTRY:  DB      20H     ; SPACE
 02D0 20           452          DB      20H     ; SPACE
 02D1 20           453          DB      20H     ; SPACE
 02D2 20           454          DB      20H     ; SPACE
 02D3 20           455          DB      20H     ; SPACE
 02D4 20           456          DB      20H     ; SPACE
 02D5 20           457          DB      20H     ; BLANK
 02D6 20           458          DB      20H     ; BLANK
 02D7 50           459          DB      50H     ; P
 02D8 72           460          DB      72H     ; R
 02D9 6F           461          DB      6FH     ; O
 02DA 63           462          DB      63H     ; C
 02DB 65           463          DB      65H     ; E
 02DC 73           464          DB      73H     ; S
 02DD 73           465          DB      73H     ; S
 02DE 20           466          DB      20H     ; BLANK
 02DF 20           467 PMIN:    DB      20H     ; BLANK
 02E0 6D           468          DB      6DH     ; M
 02E1 69           469          DB      69H     ; I
 02E2 6E           470          DB      6EH     ; N
 02E3 75           471          DB      75H     ; U
 02E4 74           472          DB      74H     ; T
 02E5 65           473          DB      65H     ; E
 02E6 73           474          DB      73H     ; S
                   475 ;
                   476          END


PUBLIC SYMBOLS
BEVNUM C 0224    FIFOCR C 0282    KDSPY2 C 0000    KDSPY3 C 00D0    KSTOR1 D 0000    KSTOR2 D 0001    KSTOR3 D 000
LOOKUP C 01E2    PNTNUM C 025A    PWRITE C 0217    SUM2   D 0003    SUM3   D 0004

EXTERNAL SYMBOLS
ALPHA  E 0000    CLEARA E 0000    CLEARB E 0000    COMM1  E 0000    COMM2  E 0000    DATA1  E 0000    DATA2  E 000
DEB    E 0000    DELAY  E 0000    DWRITE E 0000    POS1   E 0000    POS2   E 0000    PSEND  E 0000    RPOS1  E 000
```

```
USER SYMBOLS
ALPHA  E 0000   CLEARA E 0000   CLEARB E 0000   COMM1  E 0000   COMM2  E 0000   DATA1  E 0000   DATA2  E 0000
DEB    E 0000   DELAY  E 0000   DEVNUM C 0224   DEVTAB C 0252   DIG2   C 0293   DTABLE C 01E9   DWRITE E 0000
EMPTY  C 0207   FIFOCR C 0202   HUNS3  C 01D1   KDSPY2 C 0000   KDSPY3 C 00D0   KLOOK  C 0024   KLOOK3 C 00F1
KSTOR1 D 0000   KSTOR2 D 0001   KSTOR3 D 0002   LOOKUP C 01E2   NOBLK1 C 028E   NOBLN3 C 01AA   NOBLNK C 00A2
NUMTAB C 01F3   ONES2  C 00B8   ONES3  C 01B9   PENTRY C 02CF   PMIN   C 02DF   PNTNUM C 025A   POS1   E 0000
POS2   E 0000   PSEND  E 0000   PWRITE C 0217   RPOS1  E 0000   STAR   C 02BE   STOR1  C 005E   STOR13 C 0131
STOR2  C 0073   STOR23 C 0144   STOR33 C 016F   SUM2   D 0003   SUM3   D 0004   TENS2  C 00C4   TENS3  C 01C5
UNMAS  C 02C0

ASSEMBLY COMPLETE,   NO ERRORS
```

```
LOC  OBJ           LINE      SOURCE STATEMENT

                        ;***********************************************************
                        ;
                        ;        THIS PROGRAM PERFORMS ALL THE TIMING FUNCTIONS
                        ;        USED IN THE PROCESSING OF FILM WITH THE IR DEN-
                        ;        SITOMETER. SCAN TIMING IS ALSO COMPUTED HERE, BUT
                        ;        THE ACTUAL SCANS ARE TO BE MADE BY ANOTHER PROGRAM
                        ;        CALL SCAN.
                        ;        THIS PROGRAM IS EXITED WHEN ALL PROCESSING IS DONE.
                        ;
                        ;***********************************************************
                        ;
                                 NAME GODEV
                        ;
                                 PUBLIC GODEV,INVERT,MINCNT,MCNT
                        ;
                                 EXTRN IRCNT,IRBRAM,PLBYTE,LDELAY,DELAY,ALPHA,DWRITE,KDSPY2
                                 EXTRN RPB2,RPA2,DFIND,SCAN
                        ;
                                 CSEG
                        ;
0000 F3                 GODEV:   DI                         ; DISABLE INTERRUPT SYSTEM.
0001 210000   E                  LXI    H,     ALPHA
0004 36E1                        MVI    M,     0E1H         ; BLANKL ALPHA DISPLAY.
0006 CD0000   E                  CALL   DELAY               ; GIVE ALPHA TIME TO CLEAR.
0009 219801   C                  LXI    H,     PROCES       ; START OF "BEGIN?" MESSAGE.
000C 060A                        MVI    B,     0AH          ; LOAD TEXT COUNTER.
000E CD0000   E                  CALL   DWRITE              ; WRITE "BEGIN?" ON ALPHA DISPLAY.
0011 CD0000   E                  CALL   KDSPY2              ; "ENTER" KEY WILL START PROCESSING.
0014 06FF                        MVI    B,     0FFH         ; INITIALIZE SECOND AND SCAN TIME COUNTERS.
0016 48                          MOV    C,     B
0017 AF                          XRA    A                   ; ZERO A.
0018 320600   D                  STA    SCNNUM              ; SET SCAN COUNTER TO ZERO.
001B 320000   D                  STA    MINCNT              ; SET MINUTE COUNTER TO ZERO.
001E 3E01                        MVI    A,     01H          ; SET UP TASK COUNTERS.
0020 320100   D                  STA    MCNT                ; M IS I/R COMBO POINTER.
0023 320200   D                  STA    NCNT                ; N IS PROCESS # POINTER.
0026 3E00               TIMING:  MVI    A,     00H          ; SET FINTAG (FINISHED TAG) OFF.
0028 320700   D                  STA    FINTAG
002B 210000   E                  LXI    H,     IRCNT        ; HL CONTAINS START ADDRESS OF IRCNTS.
002E 3A0200   D                  LDA    NCNT
0031 85                          ADD    L
0032 6F                          MOV    L,     A            ; HL = IRCNT + NCNT.
0033 7E                          MOV    A,     M            ; A = IRCNTn.
0034 320300   D                  STA    TIRCNT              ; TIRCNT NOW HAS COPY OF IRCNTn.
0037 210000   E         TLOAD:   LXI    H,     IRBRAM       ; HL CONTAINS START ADDRESS OF IRBRAM.
003A 3A0100   D                  LDA    MCNT
003D 85                          ADD    L
003E 6F                          MOV    L,     A            ; HL POINTS TO RATEm.
003F E5                          PUSH   H
0040 CD1D01   C                  CALL   INVERT              ; CONVERT Y SCANS/MIN TO Z SECONDS/SCAN.
0043 E1                          POP    H
0044 320400   D                  STA    TRATE               ; COPY OF RATEm NOW IN TRATE.
0047 23                          INX    H                   ; HL NOW POINTS TO INTERVALm.
```

```
 LOC  OBJ         LINE        SOURCE STATEMENT

0048 7E             54         MOV    A,     M
0049 320500   D     55         STA    TINTR          ; COPY OF INTERVALn NOW IN TINTR.
004C 3A0700   D     56 RESET:  LDA    FINTAG         ; CHEC STATUS OF PROCESS FINISHED TAG.
004F FEFF           57         CPI    0FFH           ; WHEN FINTAG=FFH, THEN LAST SCAN.
0051 CAF700   C     58         JZ     RELOAD
0054 3ED8           59         MVI    A,     0D8H    ; RESET AND UN-MASK RST 7.5, & SET SOD=1
0056 30             60         SIM
0057 20             61 PEND:   RIM
0058 E640           62         ANI    40H            ; MASK TO GET RST 7.5 PENDING BIT.
005A FE00           63         CPI    00H
005C CA5700   C     64         JZ     PEND           ; WHEN ZERO DOESNT SET, THEN INTERRUPT.
005F 210000   E     65         LXI    H,     ALPHA   ; BLANK ALPHA DISPLAY WHEN PROCESS BEGINS.
0062 36E1           66         MVI    M,     0E1H
0064 0C             67         INR    C              ; INTERRUPT RECEIVED.
0065 04             68         INR    B              ; SECCNT AND SCNSEC INCREMENTED BY 1.
0066 78             69         MOV    A,     B
0067 D678           70         SUI    78H            ; IF B=60, ZEVRO FLAG WILL SET.
0069 C28400   C     71         JNZ    NOT60
006C 3A0300   D     72         LDA    TIRCNT         ; COME HERE IF SECOND COUNT = 60.
006F FE00           73         CPI    00H            ; IF ZERO SETS, THEN TIRCNT = 0.
0071 CA7B00   C     74         JZ     INC
0074 3A0500   D     75         LDA    TINTR          ; IF NOT ZERO, THEN DECREMENT TINTR.
0077 3D             76         DCR    A
0078 320500   D     77         STA    TINTR          ; UP-DATE TINTR.
007B 3A0000   D     78 INC:    LDA    MINCNT         ; INCREMENT MINUTE COUNTER.
007E 3C             79         INR    A
007F 320000   D     80         STA    MINCNT
0082 0600           81         MVI    B,     00H     ; RESET SECCNT TO 0.
0084 210000   E     82 NOT60:  LXI    H,     PLBYTE  ; LOAD HL WITH START ADDRESS OG PLBYTE.
0087 3A0200   D     83         LDA    NCNT
008A 85             84         ADD    L
008B 6F             85         MOV    L,     A       ; HL NOW POINTS TO PLBn.
008C 3A0000   D     86         LDA    MINCNT         ; TEST FOR END OF PROCESS.
008F BE             87         CMP    M
0090 C2A000   C     88         JNZ    NOTFIN         ; IF ZERO SETS, PLBn = MINCNT, PROCESS DONE.
0093 3EFF           89         MVI    A,     0FFH    ; PROCESS DONE, SET FINTAG ON, DO 1 MORE SCAN.
0095 320700   D     90         STA    FINTAG
0098 3A0000   D     91         LDA    MINCNT         ; TEST FOR ZERO PROCESS LENGTHS.
009B FE00           92         CPI    00H
009D CAEA00   C     93         JZ     SKIP
00A0 3A0200   D     94 NOTFIN: LDA    NCNT           ; TURN ON TANKn AND PUMP.
00A3 FE01           95         CPI    01H
00A5 C2AF00   C     96         JNZ    TANK2
00A8 3E43           97         MVI    A,     43H     ; TURN ON TANK 1 AND PUMP.
00AA D300     E     98         OUT    LOW RPB2       ; EXPANSION ROM PORT B.
00AC C3BF00   C     99         JMP    NOWON
00AF FE02          100 TANK2:  CPI    02H
00B1 C2BB00   C    101         JNZ    TANK3
00B4 3E4C          102         MVI    A,     4CH     ; TURN ON TANK 2 AND PUMP.
00B6 D300     E    103         OUT    LOW RPB2
00B8 C3BF00   C    104         JMP    NOWON
00BB 3E70          105 TANK3:  MVI    A,     70H     ; TURN ON TANK 3 VALVES AND PUMP.
00BD D300     E    106         OUT    LOW RPB2
00BF 3A0300   D    107 NOWON:  LDA    TIRCNT         ; TEST TO SEE IF I/R COMBOS REMAINING.
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LOC  OBJ          LINE        SOURCE STATEMENT

00C2 FE00          108          CPI     00H             ; IF TIRCNT = 0, ZERO WILL SET.
00C4 CA4C00   C    109          JZ      RESET           ; GO WAIT FOR NEXT INTERRUPT.
00C7 3A0400   D    110          LDA     TRATE           ; DO WE MAKE A SCAN?
00CA FEFF          111          CPI     0FFH            ; TEST FOR ZERO RATE FLAG.
00CC CAD300   C    112          JZ      ZRATE           ; IF ZERO RATE, BYPASS SCAN TEST.
00CF B9            113          CMP     C
00D0 CC7A01   C    114          CZ      TSCAN           ; YES. GO DO SCAN.
00D3 3A0500   D    115 ZRATE:   LDA     TINTR           ; TEST FOR END OF INTERVAL.
00D6 FE00          116          CPI     00H
00D8 C24C00   C    117          JNZ     RESET           ; IF NOT END, GO AWAIT NEXT INTERRUPT.
00DB 3A0100   D    118          LDA     MCNT
00DE C602          119          ADI     02H             ; MCNT = MCNT + 2.
00E0 320100   D    120          STA     MCNT
00E3 3A0300   D    121          LDA     TIRCNT          ; ONE I/R SET COMPLETE.
00E6 3D            122          DCR     A               ; DECREMENT TIRCNT.
00E7 320300   D    123          STA     TIRCNT
00EA 0E00          124 SKIP:    MVI     C,      00H     ; RESET SCNSEC (C REG) TO ZERO.
00EC 3A0700   D    125          LDA     FINTAG          ; CHECK TO SEE IF PROCESS DONE.
00EF FEFF          126          CPI     0FFH            ; RECALL FFH = PROCESS DONE.
00F1 CAF700   C    127          JZ      RELOAD          ; GO AND TEST FOR REMAINING PROCESSES.
00F4 C33700   C    128          JMP     TLOAD           ; GET NEW TEMPORARY I/R VALUES.
00F7 DB00     E    129 RELOAD:  IN      LOW RPB2
00F9 E63F          130          ANI     3FH             ; TURN OFF ONLY THE PUMP.
00FB D300     E    131          OUT     LOW RPB2
00FD D5            132          PUSH    D               ; SAVE CONTENTS OF DE REGISTER.
00FE CD6D01   C    133          CALL    MDELAY
0101 CD6D01   C    134          CALL    MDELAY          ; GIVE PUMP TIME TO STOP BEFORE CLOSING VALVES.
0104 D1            135          POP     D               ; RETRIVE CONTENTS OF DE REGISTER.
0105 AF            136          XRA     A               ; ZERO A.
0106 D300     E    137          OUT     LOW RPB2        ; NOW TURN OFF VALVES.
0108 320800   D    138          STA     MINCNT          ; RESET MINCNT TO ZERO.
010B 06FF          139          MVI     B,      0FFH    ; RESET SECOND ANS SCAN COUNTERS.
010D 48            140          MOV     C,      B
010E 3A0200   D    141          LDA     NCNT
0111 3C            142          INR     A               ; INCREMENT PROCESS COUNTER.
0112 320200   D    143          STA     NCNT
0115 FE04          144          CPI     04H             ; HAVE THREE PROCESSES BEEN MADE?
0117 CA0000   E    145          JZ      DFIND           ; IF YES, GO TO DATA OUT ROUTINE.
011A C32600   C    146          JMP     TIMING          ; OTHERWISE, GO GET NEXT SET OF PROCESS INFO.
011D 7E            147 INVERT:  MOV     A,      M       ; TEST TO SEE IF A ZERO RATE IS PASSED.
011E FE00          148          CPI     00H
0120 C22601   C    149          JNZ     OK              ; IF > 0, PASS BY.
0123 3EFF          150          MVI     A,      0FFH    ; OTHERWISE TAG THE RATE.
0125 C9            151          RET
0126 212F01   C    152 OK:      LXI     H,      TABLE   ; LOAD HL WITH START ADDRESS OF TABLE.
0129 5F            153          MOV     E,      A
012A 1600          154          MVI     D,      00H     ; DE = RATE SCANS/MINUTE.
012C 19            155          DAD     D               ; HL = HL + DE.
012D 7E            156          MOV     A,      M       ; HL POINTS TO RATE SEC/SCAN.
012E 07            157          RLC                     ; MULTIPLY RESULT IN A BY 2.
012F C9            158 TABLE:   RET
0130 3C            159          DB      3CH     ; FOR RATE ENTRY OF 1 SCAN/MINUTE.
0131 1E            160          DB      1EH     ; FOR ENTRY OF 2 SCAN/MINUTE.
0132 14            161          DB      14H     ; FOR 3 SCANS/MINUTE.
```

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LOC  OBJ         LINE        SOURCE STATEMENT

0133 0F           162        DB      0FH      ; 4 SCANS/MINUTE.
0134 0C           163        DB      0CH      ; 5 SCANS/MINUTE.
0135 0A           164        DB      0AH      ; 6 S/M.
0136 09           165        DB      09H      ; 7
0137 08           166        DB      08H      ; 8
0138 07           167        DB      07H      ; 9
0139 06           168        DB      06H      ; 10
013A 05           169        DB      05H      ; 11
013B 05           170        DB      05H      ; 12
013C 05           171        DB      05H      ; 13
013D 04           172        DB      04H      ; 14
013E 04           173        DB      04H      ; 15
013F 04           174        DB      04H      ; 16
0140 04           175        DB      04H      ; 17
0141 03           176        DB      03H      ; 18
0142 03           177        DB      03H      ; 19
0143 03           178        DB      03H      ; 20
0144 03           179        DB      03H      ; 21
0145 03           180        DB      03H      ; 22
0146 03           181        DB      03H      ; 23
0147 02           182        DB      02H      ; 24
0148 02           183        DB      02H      ; 25
0149 02           184        DB      02H      ; 26
014A 02           185        DB      02H      ; 27
014B 02           186        DB      02H      ; 28
014C 02           187        DB      02H      ; 29
014D 02           188        DB      02H      ; 30
014E 02           189        DB      02H      ; 31
014F 02           190        DB      02H      ; 32
0150 02           191        DB      02H      ; 33
0151 02           192        DB      02H      ; 34
0152 02           193        DB      02H      ; 35
0153 02           194        DB      02H      ; 36
0154 02           195        DB      02H      ; 37
0155 02           196        DB      02H      ; 38
0156 02           197        DB      02H      ; 38
0157 02           198        DB      02H      ; 39
0158 01           199        DB      01H      ; 40
0159 01           200        DB      01H      ; 41
015A 01           201        DB      01H      ; 42
015B 01           202        DB      01H      ; 43
015C 01           203        DB      01H      ; 44
015D 01           204        DB      01H      ; 45
015E 01           205        DB      01H      ; 46
015F 01           206        DB      01H      ; 47
0160 01           207        DB      01H      ; 48
0161 01           208        DB      01H      ; 49
0162 01           209        DB      01H      ; 50
0163 01           210        DB      01H      ; 51
0164 01           211        DB      01H      ; 52
0165 01           212        DB      01H      ; 53
0166 01           213        DB      01H      ; 54
0167 01           214        DB      01H      ; 55
0168 01           215        DB      01H      ; 56
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LOC  OBJ         LINE        SOURCE STATEMENT

0169 01           216           DB      01H      ; 57
016A 01           217           DB      01H      ; 58
016B 01           218           DB      01H      ; 59
016C 01           219           DB      01H      ; 60
016D 16FF         220 MDELAY:   MVI     D,       0FFH     ; MEDIUM LENGTH DELAY.
016F 1EFF         221 LOOP2:    MVI     E,       0FFH
0171 1D           222 LOOP1:    DCR     E
0172 C27101   C   223           JNZ     LOOP1
0175 15           224           DCR     D
0176 C26F01   C   225           JNZ     LOOP2
0179 C9           226           RET
017A 3A0600   D   227 TSCAN:    LDA     SCNNUM            ; SIMPLY INCREMENT SCAN COUNTER
017D 3C           228           INR     A                 ; UNTIL SCAN ROUTINE IS WORKED OUT.
017E 320600   D   229           STA     SCNNUM
0181 0E00         230           MVI     C,       00H      ; RESET SCNSEC TO ZERO.
0183 3E40         231           MVI     A,       40H      ; SET SOD LINE ON.
0185 30           232           SIM
0186 CD0000   E   233           CALL    DELAY             ; WAIT A BIT.
0189 3EC0         234           MVI     A,       0C0H     ; SET SOD LINE OFF.
018B 30           235           SIM
018C CD0000   E   236           CALL    SCAN
018F C9           237           RET
                  238 ;
0190 20           239 PROCES:   DB      20H      ; BLANK
0191 20           240           DB      20H      ; BLANK
0192 20           241           DB      20H      ; BLANK
0193 02           242           DB      02H      ; B
0194 05           243           DB      05H      ; E
0195 07           244           DB      07H      ; G
0196 09           245           DB      09H      ; I
0197 0E           246           DB      0EH      ; N
0198 3F           247           DB      3FH      ; ?
                  248 ;
                  249           DSEG
                  250 ;
 0000             251 MINCNT:   DS      1                 ; MINUTE COUNTER.
 0001             252 MCNT:     DS      1                 ; I/R COMBO COUNTER.
 0002             253 NCNT:     DS      1                 ; PROCESS # COUNT.
 0003             254 TIRCNT:   DS      1                 ; TEMPORARY COPY OF I/R COUNT.
 0004             255 TRATE:    DS      1                 ; TEMPORARY COPY OF CURRENT RATE VALUE.
 0005             256 TINTR:    DS      1                 ; TEMPORARY COPY OF CURRENT INTERVAL VALUE.
 0006             257 SCNNUM:   DS      1                 ; RUNNING SUM OF SCANS MADE.
 0007             258 FINTAG:   DS      1                 ; USED IN MAKING L;AST SCAN OF ANY PROCESS.
                  259 ;
                  260           END


PUBLIC SYMBOLS
GODEV  C 0000    INVERT C 011D    MINCNT D 0000    NCNT   D 0002

EXTERNAL SYMBOLS
ALPHA  E 0000    DELAY  E 0000    DFIND  E 0000    DWRITE E 0000    IRBRAM E 0000    IRCNT  E 0000    KDSPY2 E 000
LDELAY E 0000    PLBYTE E 0000    RPA2   E 0000    RPB2   E 0000    SCAN   E 0000
```

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USER SYMBOLS
ALPHA  E 0000   DELAY  E 0000   DFIND  E 0000   DWRITE E 0000   FINTAG D 0007   GODEV  C 0000   INC    C 007B
INVERT C 011D   IRBRAM E 0000   IRCNT  E 0000   KDSPY2 E 0000   LDELAY E 0000   LOOP1  C 0171   LOOP2  C 016F
MCNT   D 0001   MDELAY C 016D   MINCNT D 0000   NCNT   D 0002   NOT60  C 0084   NOTFIN C 00A0   NOWON  C 00BF
OK     C 0126   PEND   C 0057   PLBYTE E 0000   PROCES C 0190   RELOAD C 00F7   RESET  C 004C   RPA2   E 0000
RPB2   E 0000   SCAN   E 0000   SCNNUM D 0006   SKIP   C 00EA   TABLE  C 012F   TANK2  C 00AF   TANK3  C 00BB
TIMING C 0026   TINTR  D 0005   TIRCNT D 0003   TLOAD  C 0037   TRATE  D 0004   TSCAN  C 017A   ZRATE  C 00D3

ASSEMBLY COMPLETE,   NO ERRORS
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LOC  OBJ           LINE        SOURCE STATEMENT

                        ;***********************************************************************
                        ;
                        ;       THIS MODULE PROMPTS THE USER TO ENTER THE PROCESS NUMBER OF A
                        ;       PARTICULAR SCAN SERIES IN WHICH HE IS INTERESTED IN VIEWING.
                        ;
                        ;       ONCE GIVEN A PROCESS NUMBER, THE ROUTINE CHECKS TO SEE IF ANY DATA
                        ;       WAS INDEED TAKEN DURING THAT PROCESS.  IF SO, THE USER IS PROMPTED
                        ;       TO ENTER THE TIME AT WHICH HE THINKS A SCAN WAS MADE.  THE PROGRAM
                        ;       SEARCHES UNTIL IT FINDS THE CLOSEST SCAN TO THE ENTERED TIME. THIS
                        ;       DENSITY BLOCK IS DISPLAYED ALONG WITH THE ACTUAL TIME IT WAS TAKEN.
                        ;
                        ;************************************************************************
                        ;
                                NAME    DFIND
                        ;
                                PUBLIC  DFIND,SHOW,MINCON,ITEMP,TIMSUM,OFFSET,MIN
                        ;
                                EXTRN   DWRITE,KDSPY2,SUM2,DEB,IRCNT,STABCT,RAMPT,POS1,POS2,RPOS1
                                EXTRN   CLEARA,CLEARB,ALPHA,NCNT,IRBRAM,INVERT,DSHOW,MINCNT,COMM1
                                EXTRN   BINASC,LOOKUP,LDELAY,DATA1,UPORDN,PLBYTE,THPNUM
                        ;
                                CSEG
                        ;
0000 3E0D               DFIND:  MVI     A,      0DH     ; UN-MASK RST 6.5 FOR USE IN GETTING TO MONITOR
0002 30                         SIM                     ; SET INTERRUPT MASK.
0003 FB                         EI                      ; ENABLE INTERUPTS. (RST 6.5 ONLY)
0004 214302   C                 LXI     H,      TWANTM  ; PROMPT "PROCESS #=?"
0007 060C                       MVI     B,      0CH     ; LOAD TEXT COUNT.
0009 CD0000   E                 CALL    DWRITE
000C CD0000   E                 CALL    KDSPY2          ; WAIT FOR PROCESS # ENTRY.
000F 3A0000   E                 LDA     SUM2            ; VALID ENTRIES ARE 1 2 3 ONLY.
0012 FE04                       CPI     04H
0014 D20000   C                 JNC     DFIND           ; INVALID ENTRIES RETURN YOU TO DEFIND.
0017 FE00                       CPI     00H
0019 CA0000   C                 JZ      DFIND
001C 320000   E                 STA     DEB             ; STORE PROCESS ENTRY IN DEB.
001F 210000   E                 LXI     H,      IRCNT   ; LOAD HL WITH START ADDRESS OF IRCNTS.
0022 85                         ADD     L
0023 6F                         MOV     L,      A       ; HL POINTS TO IRCNT(DEB).
0024 7E                         MOV     A,      M
0025 FE00                       CPI     00H             ; IF SELECTED PROCESS HAS 0 IRCNT, "NO DATA"
0027 CC1B02   C                 CZ      NODATA
                        ;
                        ;       DETERMINE NOW HOW MANY SCANS MADE BEFORE ARRIVAL AT PROCESS WANTED.
                        ;
002A 0E00                       MVI     C,      00H
002C 3A0000   E                 LDA     DEB
002F FE01                       CPI     01H             ; IF DEB=1, START AT BOTTOM OF DRAM.
0031 CA4300   C                 JZ      ADDED
0034 47                         MOV     B,      A
0035 3A0100   E                 LDA     STABCT+1
0038 4F                         MOV     C,      A
0039 78                         MOV     A,      B
```

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LOC  OBJ         LINE        SOURCE STATEMENT

003A FE02          54        CPI    02H           ; IF DEB=2, LOAD C WITH PROCESS 1 SCAN CNT.
003C CA4300   C    55        JZ     ADDED
003F 3A0200   E    56        LDA    STABCT+2
0042 4F            57        MOV    C,     A
0043 3E01          58 ADDED: MVI    A,     01H    ; ADD 1 TO OFFSET MDMAX AND MD0 BLOCKS.
0045 81            59        ADD    C
0046 320000   E    60        STA    RAMPT         ; RAMPT = SUM OF SCANS + 2.
0049 214E02   C    61 GETTV: LXI    H,     TVMESS ; PROMPT "TIME WANTED?"
004C 060C          62        MVI    B,     0CH
004E CD0000   E    63        CALL   DWRITE
0051 3E91          64        MVI    A,     91H    ; SET KDSPY2 FOR MINUTE ENTRY.
0053 320000   E    65        STA    POS2
0056 3E82          66        MVI    A,     82H
0058 320000   E    67        STA    POS1
005B 3E62          68        MVI    A,     62H
005D 320000   E    69        STA    RPOS1
0060 3EDF          70 CLEAR: MVI    A,     0DFH   ; SET CLEAR CODE TO CLEAR ON ENTRY.
0062 320000   E    71        STA    CLEARA
0065 3ECC          72        MVI    A,     0CCH   ; SET FOR NO CLEAR ON EXIT.
0067 320000   E    73        STA    CLEARB
006A CD0000   E    74        CALL   KDSPY2        ; GET MINUTE ENTRY.
006D 3A0000   E    75        LDA    SUM2
0070 CD2C02   C    76        CALL   MINCON        ; CONVERT MINUTES TO SECONDS.
0073 220000   D    77        SHLD   TVANT         ; TVANT= MINUTE ENTRY IN SECONDS.
0076 3E94          78        MVI    A,     94H    ; SET KDSY2 FOR SECOND ENTRY.
0078 320000   E    79        STA    POS2
007B 3E85          80        MVI    A,     85H
007D 320000   E    81        STA    POS1
0080 3E65          82        MVI    A,     65H
0082 320000   E    83        STA    RPOS1
0085 3ECC          84 CLEARS: MVI   A,     0CCH   ; SET FOR NO CLEAR ON ENTRY TO KDSPY2.
0087 320000   E    85        STA    CLEARA
008A 3EDF          86        MVI    A,     0DFH   ; SET CLEAR CODE TO CLEAR ON EXIT.
008C 320000   E    87        STA    CLEARR
008F CD0000   E    88        CALL   KDSPY2        ; GET SECONDS ENTRY.
0092 2A0000   D    89        LHLD   TVANT
0095 3A0000   E    90        LDA    SUM2          ; ADD SECONDS TO TVANT.
0098 4F            91        MOV    C,     A
0099 0600          92        MVI    B,     00H
009B 09            93        DAD    B
009C 220000   D    94        SHLD   TVANT
009F 7C            95        MOV    A,     H      ; TEST TO SEE IF TVANT = 0.
00A0 FE00          96        CPI    00H
00A2 C2AB00   C    97        JNZ    TVNOT0
00A5 7D            98        MOV    A,     L
00A6 FE00          99        CPI    00H
00A8 CA4900   C   100        JZ     GETTV         ; IF IT IS, GET ANOTHER TVANT ENTRY.
00AB 210000   E   101 TVNOT0: LXI   H,     PLBYTE ; PREPARE TO TEST TVANT AGAINST LENGTH
00AE 3A0000   E   102        LDA    DEB           ; OF SELECTED PROCESS.
00B1 85           103        ADD    L
00B2 6F           104        MOV    L,     A      ; HL POINTS TO SELECTED PLBYTE(DEB)
00B3 7E           105        MOV    A,     M
00B4 CD2C02   C   106        CALL   MINCON        ; CONVERT PLBYTE TO SECONDS.
00B7 3A0100   D   107        LDA    TVANT+1       ; COMPARE HOB OF TVANT TO HOB OF PLBYTE.
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 LOC  OBJ         LINE        SOURCE STATEMENT

 00BA BC           108        CMP    H
 00BB DAD600   C   109        JC     OVER              ; A CY MEANS HO TWANT < HO PLBYTE.
 00BE C2CB00   C   110        JNZ    BLINK             ; NO ZERO MEANS HO TWANT > HO PLBYTE.
 00C1 3A0000   D   111        LDA    TWANT             ; NOW TEST LOBS.
 00C4 BD           112        CMP    L
 00C5 DAD600   C   113        JC     OVER              ; A CY MEANS LO TWANT < LO PLBYTE.
 00C8 CAD600   C   114        JZ     OVER              ; A ZERO MEANS = AND THATS O.K. TOO.
 00CB 3ECB         115 BLINK: MVI    A,      0CBH      ; BLINK ALPHA AS TWANT > PLB(DER).
 00CD 320000   E   116        STA    ALPHA
 00D0 CD0000   E   117        CALL   LDELAY
 00D3 C30000   C   118        JMP    DFIND             ; GO START OVER AGAIN.
 00D6 AF           119 OVER:  XRA    A                 ; INITIALIZE N (I/R COUNTER).
 00D7 320000   E   120        STA    NCNT
 00DA 67           121        MOV    H,      A
 00DB 6F           122        MOV    L,      A         ; ZERO RUNNING SUM  :  TIMSUM.
 00DC 220200   D   123        SHLD   TIMSUM
 00DF 4F           124        MOV    C,      A
 00E0 210100   E   125        LXI    H,      IRCNT+1   ; SUM IRCNTS TO GET START ADDRESS IN
 00E3 3A0000   E   126        LDA    DER               ; IRBRAM SPACE
 00E6 FE01         127 SUMIR: CPI    01H               ; NOTE THAT IF PROCESS 1 IS SELECTED, YOU
 00E8 CAF500   C   128        JZ     NOSUM             ; WISH TO START AT THE VERY BOTTOM OF IRBRAM.
 00EB 47           129        MOV    B,      A
 00EC 79           130        MOV    A,      C
 00ED 86           131        ADD    M
 00EE 4F           132        MOV    C,      A
 00EF 78           133        MOV    A,      B
 00F0 3D           134        DCR    A
 00F1 23           135        INX    H
 00F2 C3E600   C   136        JMP    SUMIR
 00F5 79           137 NOSUM: MOV    A,      C         ; RETRIEVE IRCNT SUM.
 00F6 87           138        ADD    A                 ; DOUBLE IT.
 00F7 C601         139        ADI    01H               ; ADD 1 TO GET OFF IRCNT.
 00F9 320600   D   140        STA    OFFSET            ; OFFSET MUST BE ADDED TO IRBRAM TO PUT
 00FC 210000   E   141        LXI    H,      IRBRAM    ; YOU IN THE PROCESS IR BLOCK YOU'VE
 00FF 5F           142        MOV    E,      A         ; SELECTED.
 0100 1600         143        MVI    D,      00H       ; DE = OFFSET.
 0102 19           144        DAD    D                 ; HL = IRBRAM + OFFSET.
 0103 23           145        INX    H                 ; INCREMENT TO MOVE FROM R TO I.
 0104 7E           146        MOV    A,      M         ; MOVE INTERVAL INTO A REG.
 0105 CD2C02   C   147        CALL   MINCON            ; CONVERT TO SECONDS.
 0108 220400   D   148        SHLD   ITEMP
 010B 2A0000   D   149 WRDTST: LHLD  TWANT             ; IS TIMSUM >/= TWANT ?
 010E 3A0300   D   150        LDA    TIMSUM+1          ; TEST HOBS FIRST.
 0111 BC           151        CMP    H
 0112 DA1F01   C   152        JC     TSLSTW
 0115 C29A01   C   153        JNZ    SHOW
 0118 3A0200   D   154        LDA    TIMSUM            ; TEST LOBS LAST.
 011B BD           155        CMP    L
 011C D29A01   C   156        JNC    SHOW
 011F 2A0400   D   157 TSLSTW: LHLD  ITEMP             ; IS TIMSUM = ITEMP ?
 0122 3A0300   D   158        LDA    TIMSUM+1          ; TEST HOBS FIRST.
 0125 BC           159        CMP    H
 0126 C23001   C   160        JNZ    ADDWRD
 0129 3A0200   D   161        LDA    TIMSUM            ; TEST LOBS LAST.
```

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LOC  OBJ         LINE        SOURCE STATEMENT

012C BD           162          CMP    L
012D CA5801  C    163          JZ     INCN
0130 3A0000  E    164 ADDWRD:  LDA    RAMPT          ; COME HERE IF TIMSUM NOT EQUAL TO ITEMP.
0133 3C           165          INR    A
0134 320000  E    166          STA    RAMPT          ; RAMPT = RAMPT + 1
                  167 ;
                  168 ;        CALCULATE R(N) POINTER BY: IRBRAM + OFFSET + 2(NCNT)
                  169 ;
0137 3A0000  E    170          LDA    NCNT
013A 87           171          ADD    A              ; DOUBLE NCNT
013B 47           172          MOV    B,    A
013C 3A0600  D    173          LDA    OFFSET
013F 80           174          ADD    B              ; A = OFFSET + 2(NCNT).
0140 0600         175          MVI    B,    00H
0142 4F           176          MOV    C,    A        ; BC = OFFSET + 2(NCNT).
0143 210000  E    177          LXI    H,    IRBRAM
0146 09           178          DAD    B              ; HL = IRBRAM + OFFSET + 2(NCNT).
0147 CD0000  E    179          CALL   INVERT         ; CONVERT RATE FROM SCAN/MIN TO SEC/SCAN.
014A 0F           180          RRC                   ; DIVIDE RESULT BY 2.
014B 4F           181          MOV    C,    A        ; C = RATE N IN SEC/SCAN.
014C 0600         182          MVI    B,    00H
014E 2A0200  D    183          LHLD   TIMSUM
0151 09           184          DAD    B              ; HL = TIMSUM + R(N)
0152 220200  D    185          SHLD   TIMSUM
0155 C30B01  C    186          JMP    WRDTST
0158 3A0000  E    187 INCN:    LDA    NCNT           ; N = N + 1
015B 3C           188          INR    A
015C 320000  E    189          STA    NCNT
015F 210000  E    190          LXI    H,    IRCNT    ; IRCNT(DEB) = N ?
0162 3A0000  E    191          LDA    DEB
0165 85           192          ADD    L
0166 6F           193          MOV    L,    A        ; HL POINTS TO IRCNT(DEB).
0167 3A0000  E    194          LDA    NCNT
016A BE           195          CMP    M
016B CA8B01  C    196          JZ     LASSCN
016E 87           197          ADD    A              ; DOUBLE NCNT.
016F 47           198          MOV    B,    A        ; STORE COPY OF NCNT IN B REG.
0170 3A0600  D    199          LDA    OFFSET
0173 80           200          ADD    B              ; A = 2(NCNT) + OFFSET.
0174 3C           201          INR    A              ; A = 2(NCNT) + OFFSET + 1
0175 4F           202          MOV    C,    A
0176 0600         203          MVI    B,    00H      ; BC = 2(NCNT) + OFFSET + 1
0178 210000  E    204          LXI    H,    IRBRAM
017B 09           205          DAD    B              ; HL = IRBRAM +2(NCNT) + OFFSET + 1
017C 7E           206          MOV    A,    M
017D CD2C02  C    207          CALL   NINCON         ; CONVERT I(N) TO SECONDS.
0180 EB           208          XCHG                  ; STORE THID IN DE.
0181 2A0400  D    209          LHLD   ITEMP
0184 19           210          DAD    D              ; HL = ITEMP + I(N) .
0185 220400  D    211          SHLD   ITEMP          ; ITEMP = ITEMP + I(N).
0188 C33001  C    212          JMP    ADDWRD
018B 210000  E    213 LASSCN:  LXI    H,    NCNT     ; N = N-1.
018E 35           214          DCR    M
018F 216502  C    215          LXI    H,    LSCNM    ; PROMPT "LAST SCAN"
```

```
 LOC  OBJ         LINE        SOURCE STATEMENT

 0192 060B         216          MVI     B,      0BH
 0194 CD0000   E   217          CALL    DWRITE
 0197 CD0000   E   218          CALL    LDELAY
 019A CD0000   E   219 SHOW:    CALL    DSHOW           ; DISPLAY DENSITY BLOCK POINTED TO BY RAMPT
                   220 ;
                   221 ;        NOW DISPLAY CONTENTS OF TIMSUM AS: MIN:SEC .
                   222 ;
 019D AF           223          XRA     A               ; ZERO A AND SET CY TO 0.
 019E 320900   D   224          STA     MIN             ; ZERO MINUTE COUNTER.
 01A1 2A0200   D   225          LHLD    TIMSUM          ; STORE COPY OF TIMSUM IN MINUTE.
 01A4 220000   E   226          SHLD    TMPNUM          ; STORE COPY FOR LATER RETRIVAL.
 01A7 220700   D   227          SHLD    MINUTE
 01AA 2A0700   D   228 CHANGE:  LHLD    MINUTE          ; STORE COPY OF MINUTE IN TIMSUM.
 01AD 220200   D   229          SHLD    TIMSUM
 01B0 063C         230          MVI     B,      3CH     ; B=60 ( 60 SECONDS IN A MINUTE ASSHOLE!).
 01B2 3A0700   D   231          LDA     MINUTE          ; LOB FIRST: MINUTE = MINUTE - 60.
 01B5 98           232          SBB     B               ; A = MINUTE - 60.
 01B6 320700   D   233          STA     MINUTE
 01B9 D2C801   C   234          JNC     NOBROW          ; NO CY IMPLIES NO NEED TO BORROW.
 01BC 0600         235          MVI     B,      00H     ; IF CY, BORROW 1 FROM HOB OF MINUTE.
 01BE 3A0800   D   236          LDA     MINUTE+1
 01C1 98           237          SBB     B
 01C2 320800   D   238          STA     MINUTE+1
 01C5 FAD201   C   239          JM      SHOWTS          ; IF HOB NEGATIVE, THEN EXIT.
 01C8 3A0900   D   240 NOBROW:  LDA     MIN             ; INCREMENT MINUTE COUNTER.
 01CB 3C           241          INR     A
 01CC 320900   D   242          STA     MIN
 01CF C3AA01   C   243          JMP     CHANGE
 01D2 215902   C   244 SHOWTS:  LXI     H,      TPAST   ; PROMPT "TIME ELASPED"
 01D5 060D         245          MVI     B,      0DH
 01D7 CD0000   E   246          CALL    DWRITE
 01DA 3A0900   D   247          LDA     MIN             ; CONVERT MIN TO ASCII.
 01DD CD0000   E   248          CALL    BINASC
 01E0 7A           249          MOV     A,      D       ; D CONTAINS 10'S PLACE ASCII.
 01E1 D630         250          SUI     30H             ; CONVERT TO SIMPLE BCD.
 01E3 41           251          MOV     B,      C       ; HIDE C FOR A SEC.
 01E4 CD0000   E   252          CALL    LOOKUP          ; CONVERT BCD TO DISPLAY CODE.
 01E7 51           253          MOV     D,      C       ; D NOW CONTAINS 10'S PLACE MINUTE CODE.
 01E8 78           254          MOV     A,      B       ; DO NOW FOR 1'S PLACE MINUTE COUNT.
 01E9 D630         255          SUI     30H
 01EB CD0000   E   256          CALL    LOOKUP
 01EE 210000   E   257          LXI     H,      COMM1
 01F1 3691         258          MVI     M,      91H     ; SET CONTROL DISPLAY FOR POS. 1 (AI).
 01F3 210000   E   259          LXI     H,      DATA1
 01F6 72           260          MOV     M,      D       ; SEND 10'S PLACE MINUTE CODE TO DISPLAY.
 01F7 71           261          MOV     M,      C       ; SEND 1'S PLACE MINUTE CODE TO DISPLAY.
 01F8 36FF         262          MVI     M,      0FFH    ; SEND BLANK TO SEPERATE MIN FROM SEC.
 01FA E5           263          PUSH    H               ; SAVE DISPLAY ADDRESS.
 01FB 3A0200   D   264          LDA     TIMSUM          ; DO NOW FOR SECOND COUNT.
 01FE CD0000   E   265          CALL    BINASC
 0201 7A           266          MOV     A,      D       ; D CONTAINS 10'S PLACE SECOND COUNT.
 0202 D630         267          SUI     30H
 0204 41           268          MOV     B,      C
 0205 CD0000   E   269          CALL    LOOKUP          ; CONVERT 10'S BCD TO DISPLAY CODE.
```

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LOC  OBJ          LINE        SOURCE STATEMENT

0208 51            270          MOV     D,      C
0209 78            271          MOV     A,      B
020A D630          272          SUI     30H
020C CD0000    E   273          CALL    LOOKUP
020F E1            274          POP     H               ; RETREIVE DISPLAY ADDRESS.
0210 72            275          MOV     M,      D       ; SEND 10'S PLACE SECOND COUNT.
0211 71            276          MOV     M,      C       ; SEND 1'S PLACE SECOND COUNT TO DISPLAY.
                   277 ;
0212 2A0000    E   278          LHLD    TMPNUM          ; RESTORE TIMSUM TO ITS ORIGINAL VALUE.
0215 220200    D   279          SHLD    TIMSUM
                   280 ;
                   281 ;        AT THIS POINT DENSITY VALUES ALONG WITH TIME ELASPED SHOULD BE
                   282 ;        ON THE TWO DISPLAYS.
                   283 ;
0218 C30000    E   284          JMP     UPORDN          ; GO TO SELECT DATA UP, DATA DOWN OR RETURN.
                   285 ;
                   286 ;****************************
                   287 ;
                   288 ;        SUBROUTINES FOLLOW
                   289 ;
                   290 ;****************************
                   291 ;
                   292 ;
                   293 ;***********************************************************************
                   294 ;
                   295 ;    **  NODATA  **
                   296 ;
                   297 ;        THIS SUBROUTINE DISPLAYS " NO DATA " ON THE ALPHA DISPLAY.
                   298 ;        IT ALSO POPS THE STACK AND PLACES A NEW RETURN ADDRESS OF
                   299 ;        DFIND ONTO THE STACK.
                   300 ;
                   301 ;***********************************************************************
                   302 ;
021B 213A02    C   303 NODATA: LXI     H,      NODATM  ; START ADDRESS OF "NO DATA"
021E 060A          304          MVI     B,      0AH
0220 CD0000    E   305          CALL    DWRITE
0223 CD0000    E   306          CALL    LDELAY
0226 E1            307          POP     H
0227 210000    C   308          LXI     H,      DFIND
022A E5            309          PUSH    H
022B C9            310          RET
                   311 ;
                   312 ;***********************************************************************
                   313 ;
                   314 ;    **  MINCON  **
                   315 ;
                   316 ;        THIS ROUTINE CONVERTS MINUTES TO SECONDS.
                   317 ;
                   318 ;        PASS:   A CONTAINS THE NUMBER OF MINUTES.
                   319 ;
                   320 ;        RETURN:  HL CONTAINS THE RESULT OF A X 60 IN SECONDS.
                   321 ;
                   322 ;***********************************************************************
                   323 ;
```

```
LOC  OBJ          LINE        SOURCE STATEMENT

022C 210000        324 MINCON: LXI     H,      0000H
022F 013C00        325         LXI     B,      003CH          ; LOAD B WITH 60.
0232 FE00          326 MINADD: CPI     00H
0234 C8            327         RZ
0235 09            328         DAD     B
0236 3D            329         DCR     A
0237 C33202   C    330         JMP     MINADD
                   331 ;
                   332 ;       DISPLAY MESSAGES FOLLOW:
                   333 ;
023A 20            334 NODATM: DB      20H     ; BLANK
023B 20            335         DB      20H     ; BLANK
023C 0E            336         DB      0EH     ; N
023D 0F            337         DB      0FH     ; O
023E 20            338         DB      20H     ; BLANK
023F 04            339         DB      04H     ; D
0240 01            340         DB      01H     ; A
0241 14            341         DB      14H     ; T
0242 01            342         DB      01H     ; A
0243 10            343 TWANTM: DB      10H     ; P
0244 12            344         DB      12H     ; R
0245 0F            345         DB      0FH     ; O
0246 03            346         DB      03H     ; C
0247 05            347         DB      05H     ; E
0248 13            348         DB      13H     ; S
0249 13            349         DB      13H     ; S
024A 20            350         DB      20H     ; BLANK
024B 23            351         DB      23H     ; #
024C 3D            352         DB      3DH     ; =
024D 3F            353         DB      3FH     ; ?
024E 14            354 TWMESS: DB      14H     ; T
024F 09            355         DB      09H     ; I
0250 0D            356         DB      0DH     ; M
0251 05            357         DB      05H     ; E
0252 20            358         DB      20H     ; BLANK
0253 17            359         DB      17H     ; W
0254 01            360         DB      01H     ; A
0255 0E            361         DB      0EH     ; N
0256 14            362         DB      14H     ; T
0257 05            363         DB      05H     ; E
0258 04            364         DB      04H     ; D
0259 14            365 TPAST:  DB      14H     ; T
025A 09            366         DB      09H     ; I
025B 0D            367         DB      0DH     ; M
025C 05            368         DB      05H     ; E
025D 20            369         DB      20H     ; BLANK
025E 05            370         DB      05H     ; E
025F 0C            371         DB      0CH     ; L
0260 01            372         DB      01H     ; A
0261 13            373         DB      13H     ; S
0262 10            374         DB      10H     ; P
0263 05            375         DB      05H     ; E
0264 04            376         DB      04H     ; D
0265 20            377 LSCNM:  DB      20H     ; BLANK
```

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  LOC  OBJ         LINE        SOURCE STATEMENT

 0266 0C            378         DB      0CH     ; L
 0267 01            379         DB      01H     ; A
 0268 13            380         DB      13H     ; S
 0269 14            381         DB      14H     ; T
 026A 20            382         DB      20H     ; BLANK
 026B 13            383         DB      13H     ; S
 026C 03            384         DB      03H     ; C
 026D 01            385         DB      01H     ; A
 026E 0E            386         DB      0EH     ; N
                    387 ;
                    388         DSEG
                    389 ;
 0000               390 TWANT:  DS      02H     ; TIME WANTED IN SECONDS.
 0002               391 TIMSUM: DS      02H     ; 2 BYTE RUNNING SUM OF RATES ( ALSO IN SECONDS).
 0004               392 ITEMP:  DS      02H     ; LENGTH OF I(N) IN SECONDS.
 0006               393 OFFSET: DS      01H     ; USED IN JUMPING I/R BLOCKS.
 0007               394 MINUTE: DS      02H     ; PARTNER TO TIMSUM.
 0009               395 MIN:    DS      01H     ; MINUTE COUNTER.
                    396 ;
                    397         END


PUBLIC SYMBOLS
DFIND  C 0000   ITEMP  D 0004   MIN    D 0009   MINCON C 022C   OFFSET D 0006   SHOW   C 019A   TIMSUM D 0002

EXTERNAL SYMBOLS
ALPHA  E 0000   BINASC E 0000   CLEARA E 0000   CLEARB E 0000   COMM1  E 0000   DATA1  E 0000   DER    E 0000
DSHOW  E 0000   DWRITE E 0000   INVERT E 0000   IRBRAM E 0000   IRCNT  E 0000   KDSPY2 E 0000   LDELAY E 0000
LOOKUP E 0000   MINCNT E 0000   NCNT   E 0000   PLBYTE E 0000   POS1   E 0000   POS2   E 0000   RAMPT  E 0000
RPOS1  E 0000   STABCT E 0000   SUM2   E 0000   TMPNUM E 0000   UPORDN E 0000

USER SYMBOLS
ADDED  C 0043   ADDWRD C 0130   ALPHA  E 0000   BINASC E 0000   BLINK  C 00CB   CHANGE C 01AA   CLEAR  C 0060
CLEARA E 0000   CLEARB E 0000   CLEARS C 0085   COMM1  E 0000   DATA1  E 0000   DER    E 0000   DFIND  C 0000
DSHOW  E 0000   DWRITE E 0000   GETTW  C 0049   INCN   C 0158   INVERT E 0000   IRBRAM E 0000   IRCNT  E 0000
ITEMP  D 0004   KDSPY2 E 0000   LASSCN C 010B   LDELAY E 0000   LOOKUP E 0000   LSCNM  C 0265   MIN    D 0009
MINADD C 0232   MINCNT E 0000   MINCON C 022C   MINUTE D 0007   NCNT   E 0000   NORROW C 01C8   NODATA C 021B
NODATM C 023A   NOSUM  C 00F5   OFFSET D 0006   OVER   C 00D6   PLBYTE E 0000   POS1   E 0000   POS2   E 0000
RAMPT  E 0000   RPOS1  E 0000   SHOW   C 019A   SHOWTS C 01D2   STABCT E 0000   SUM2   E 0000   SUMIR  C 00E6
TIMSUM D 0002   TMPNUM E 0000   TPAST  C 0259   TSLSTW C 011F   TWANT  D 0000   TWANTM C 0243   TWMESS C 024E
TWNOT0 C 00AB   UPORDN E 0000   WRDTST C 010B

ASSEMBLY COMPLETE,  NO ERRORS
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LOC  OBJ          LINE        SOURCE STATEMENT

                         ;*********************************************************************
                         ;
                         ;         UPORDN   (UP OR DOWN) IS A KEYBOARD READ/COMMAND ROUTINE THAT
                         ;         PERFORMS 5 DIFFERENT FUNCTIONS DEPENDING WHAT KEY IS DEPRESSED.
                         ;
                         ;         THESE FUNCTIONS ARE:
                         ;
                         ;         KEY                FUNCTION
                         ;
                         ;         UP                 THIS MOVES USER UP TO NEXT SEQUENTIAL DENSITY SCAN.
                         ;
                         ;         DOWN               THIS MOVES USER DOWN TO PRECEEDING DENSITY SCAN.
                         ;
                         ;         PRT                THIS WILL PRINT ALL ELEVEN DENSITY VALUES ON THE
                         ;                            40-COLUMN PRINTER THAT ARE CURRENTLY DISPLAYED.
                         ;
                         ;         NXT                RETURNS USER TO ENTER PROCESS PROMPT AS TO ALLOW
                         ;                            FOR VIEWING DATA IN A DIFFERENT NUMBER PROCESS.
                         ;
                         ;     ENTER-ENTER            TWO ENTERS IN A ROW WILL RETURN USEB TO PROCESS
                         ;                            INFORMATION ENTRY ROUTINE TO ALLOW FOR ANOTHER PROCESS.
                         ;
                         ;*********************************************************************
                         ;
                                   NAME    UPORDN
                         ;
                                   PUBLIC  UPORDN
                         ;
                                   EXTRN   ITEMP,TIMSUM,RAMPT,NCNT,OFFSET,IRBRAM,DEB,FIFOCR,COMM2
                                   EXTRN   DATA2,MANFLG,START,DFIND,INVERT,SHOW,IRCNT,MINCON,DWRITE
                                   EXTRN   DRAM,NXDRAM,RPOS1,POS1,POS2,CLEARA,CLEARB,MIN
                                   EXTRN   TDSTOR,PWRITE,PSEND,COMM1,DATA1,MANMOD,SUM2,KDSPY2,RPA2
                         ;
                                   CSEG
                         ;
0000 CDF902   C          UPORDN:   CALL    RESET          ; RESET RESETS PARAMETERS USED IN KDSPY2.
0003 CD0000   E                    CALL    FIFOCR         ; CLEAR FIFO.
0006 210000   E          KLOOK:    LXI     H,      COMM2  ; 8279 STATUS WORD ADDRESS.
0009 7E                            MOV     A,      M
000A E603                          ANI     03H            ; MASK OUT 5 HI-ORDER BITS.
000C FE01                          CPI     01H            ; IF SOMETHING IN FIFO, ZERO WILL SET.
000E C20600   C                    JNZ     KLOOK          ; IF NOT, KEEP LOOKING.
0011 3640                          MVI     M,      40H    ; SET FIFO AS READ SOURCE.
0013 210000   E                    LXI     H,      DATA2  ; DATA ADDRESS OF EXPANSION 8279.
0016 7E                            MOV     A,      M      ; PUT FIFO CONTENTS INTO A REG.
0017 E60F                          ANI     0FH            ; MASK OUT HI-ORDER NIBBLE.
0019 FE0F                          CPI     0FH            ; IS IT ENTER KEY?
001B C22000   C                    JNZ     NEKEY
001E 3A0000   E                    LDA     MANFLG         ; CHECK FOR TWO CONCURRENT ENTERS.
0021 3C                            INR     A
0022 320000   E                    STA     MANFLG
0025 FE02                          CPI     02H
0027 CA5903   C                    JZ      CLEAN          ; YES, 2 ENTERS; GO TO MANUAL MODE TEST.
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LOC  OBJ         LINE        SOURCE STATEMENT

002A C30600   C    54        JMP    KLOOK           ; GO LOOK FOR ANOTHER ENTRY.
002D 47            55 NEKEY: MOV    B,      A
002E AF            56        XRA    A
002F 320000   E    57        STA    MANFLG          ; SECOND DEPRESSION NOT ENTER, RESET MANFLG.
0032 78            58        MOV    A,      B
0033 FE0E          59        CPI    0EH
0035 CA4A00   C    60        JZ     NEXTUP          ; THIS IS INCREMENT UP ROUTINE.
0038 FE0D          61        CPI    0DH
003A CAC000   C    62        JZ     NEXTDN          ; THIS DECREMENT DOWN ROUTINE.
003D FE0C          63        CPI    0CH
003F CA5201   C    64        JZ     PRINT           ; THIS PRINTS CURRENT DISPLAY CONTENTS.
0042 FE0B          65        CPI    0BH
0044 CA0000   E    66        JZ     DFIND           ; GO TO SELECT NEW PROCESS #.
0047 C30000   C    67        JMP    UPORDN          ; ALL OTHER ENTRIES INVALID, GO LOOK AGAIN.
004A 2A0000   E    68 NEXTUP: LHLD  ITEMP           ; IS TIMSUM = ITEMP?
004D 3A0100   E    69        LDA    TIMSUM+1
0050 BC            70        CMP    H
0051 C25B00   C    71        JNZ    NOTEQ           ; IF HOB'S NOT EQUAL, THEN LEAVE.
0054 3A0000   E    72        LDA    TIMSUM
0057 BD            73        CMP    L
0058 CA8300   C    74        JZ     INKN
005B 3A0000   E    75 NOTEQ: LDA    RAMPT           ; COME HERE IF TIMSUM NOT EQ TO ITEMP.
005E 3C            76        INR    A
005F 320000   E    77        STA    RAMPT           ; RAMPT = RAMPT + 1.
                   78 ;
                   79 ;      CALCULATE R(N) POINTER BY: IRRRAM + OFFSET + 2(NCNT)
                   80 ;
0062 3A0000   E    81        LDA    NCNT
0065 87            82        ADD    A               ; DOUBLE NCNT
0066 47            83        MOV    B,      A
0067 3A0000   E    84        LDA    OFFSET
006A 80            85        ADD    B               ; A = OFFSET + 2(NCNT).
006B 0600          86        MVI    B,      00H
006D 4F            87        MOV    C,      A       ; BC = OFFSET + 2(NCNT).
006E 210000   E    88        LXI    H,      IRRRAM
0071 09            89        DAD    B               ; HL = IRRRAM + OFFSET + 2(NCNT).
0072 CD0000   E    90        CALL   INVERT          ; CONVERT RATE FROM SCAN/MIN TO SEC/SCAN.
0075 0F            91        RRC                    ; DIVIDE RESULT BY 2.
0076 4F            92        MOV    C,      A
0077 0600          93        MVI    B,      00H
0079 2A0000   E    94        LHLD   TIMSUM
007C 09            95        DAD    B               ; HL = TIMSUM + R(N).
007D 220000   E    96        SHLD   TIMSUM          ; UPDATE TIMSUM.
0080 C30000   E    97        JMP    SHOW            ; DISPLAY DENSITIES POINTED TO BY RAMPT.
0083 210000   E    98 INKN:  LXI    H,      IRCNT   ; IRCNT(DEB) = N !
0086 3A0000   E    99        LDA    DEB
0089 85           100        ADD    L
008A 6F           101        MOV    L,      A       ; HL POINTS TO IRCNT(DEB).
008B 56           102        MOV    D,      M
008C 15           103        DCR    D
008D 3A0000   E   104        LDA    NCNT
0090 BA           105        CMP    D
0091 CAB500   C   106        JZ     NMDATA          ; IF EQUAL, GO DISPLAY "NO MORE DATA"
0094 3C           107        INR    A               ; IF NOT EQUAL, ITEMP = ITEMP + I(N).
```

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LOC  OBJ          LINE        SOURCE STATEMENT

0095 320000   E   108         STA     NCNT
0098 87           109         ADD     A                 ; DOUBLE NCNT.
0099 47           110         MOV     B,      A         ; GENERATE ITEMP = ITEMP + I(N).
009A 3A0000   E   111         LDA     OFFSET
009D 80           112         ADD     B                 ; A = OFFSET + 2(NCNT).
009E 3C           113         INR     A                 ; A = OFFSET + 2(NCNT) + 1.
009F 4F           114         MOV     C,      A
00A0 0600         115         MVI     B,      00H       ; BC = OFFSET + 2(NCNT) + 1.
00A2 210000   E   116         LXI     H,      IRBRAM
00A5 09           117         DAD     B                 ; HL = OFFSET + 2(NCNT) + 1 + IRBRAM.
00A6 7E           118         MOV     A,      M
00A7 CD0000   E   119         CALL    MINCON            ; CONVERT I(N) TO SECONDS.
00AA EB           120         XCHG                      ; STORE THID IN DE REGISTER.
00AB 2A0000   E   121         LHLD    ITEMP
00AE 19           122         DAD     D
00AF 220000   E   123         SHLD    ITEMP             ; ITEMP = ITEMP + I(N).
00B2 C35E00   C   124         JMP     NOTEQ
00B5 217303   C   125 NMDATA: LXI     H,      NMDATM    ; DISPLAY "NO MORE DATA"
00B8 060D         126         MVI     B,      0DH       ; LOAD TEXT COUNTER.
00BA CD0000   E   127         CALL    DWRITE
00BD C30000   C   128         JMP     UPORDN            ; LOOK FOR MORE KEY COMMANDS.
00C0 AF           129 NEXTDN: XRA     A                 ; CONVERT ITEMP BACK TO MINUTES.
00C1 320000   E   130         STA     MIN
00C4 2A0000   E   131         LHLD    ITEMP
00C7 EB           132         XCHG                      ; PUT COPY OF ITEMP INTO DE.
00C8 7B           133 OMT:    MOV     A,      E         ; LOB OF ITEMP INTO A.
00C9 063C         134         MVI     B,      3CH       ; B=60.
00CB 98           135         SBB     B
00CC 5F           136         MOV     E,      A         ; UPDATE E REG.
00CD D2D800   C   137         JNC     NOBARO
00D0 7A           138         MOV     A,      D         ; NOW DO HOB'S.
00D1 0600         139         MVI     B,      00H
00D3 98           140         SBB     B
00D4 57           141         MOV     D,      A         ; UPDATE D REG.
00D5 FADF00   C   142         JM      DONE              ; WHEN HIB GOES NEGATIVE, THEN DONE.
00D8 210000   E   143 NOBARO: LXI     H,      MIN       ; INCREMENT MINUTE COUNTER.
00DB 34           144         INR     M
00DC C3C800   C   145         JMP     OMT
00DF 3A0000   E   146 DONE:   LDA     NCNT              ; PERFORM LITEMP = ITEMP - I(N) IN MINUTES.
00E2 87           147         ADD     A                 ; GET I(N) FIRST.
00E3 47           148         MOV     B,      A
00E4 3A0000   E   149         LDA     OFFSET
00E7 80           150         ADD     B                 ; A=2(NCNT) + OFFSET.
00E8 3C           151         INR     A                 ; A = 2(NCNT) + OFFSET + 1.
00E9 4F           152         MOV     C,      A
00EA 0600         153         MVI     B,      00H
00EC 210000   E   154         LXI     H,      IRBRAM
00EF 09           155         DAD     B                 ; HL = IRBRAM + 2(NCNT) + OFFSET + 1.
00F0 3A0000   E   156         LDA     MIN               ; PLACE MINUTE VERSION OF ITEMP IN A.
00F3 96           157         SUB     M                 ; A = ITEMP - I(N) ; ALL IN MINUTES.
00F4 CD0000   E   158         CALL    MINCON            ; CONVERT RESULT TO SECONDS.
00F7 220000   D   159         SHLD    LITEMP            ; LITEMP = ITEMP - I(N), NOW IN SECONDS.
00FA EB           160         XCHG                      ; PLACE COPY IN DE.
00FB 2A0000   E   161         LHLD    TIMSUM            ; TIMSUM = LITEMP !??
```

168

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LOC  OBJ          LINE        SOURCE STATEMENT

00FE 7C            162        MOV    A,     H
00FF BA            163        CMP    D              ; TEST HOB'S FIRST.
0100 C21A01   C    164        JNZ    DECKS          ; GO TO DECKS IF HOB'S NOT EQUAL.
0103 7D            165        MOV    A,     L
0104 BB            166        CMP    E              ; TEST LOB'S.
0105 C21A01   C    167        JNZ    DECKS          ; GO TO DECKS IF LOB'S NOT EQUAL.
0108 3A0000   E    168 NEQ0:  LDA    NCNT           ; N = 0 ??????
010B FE00          169        CPI    00H
010D CAB500   C    170        JZ     NMDATA         ; IF NOT EQUAL TO 0, THEN N = N-1.
0110 3D            171        DCR    A
0111 320000   E    172        STA    NCNT
0114 2A0000   D    173        LHLD   LITEMP         ; SET ITEMP = LITEMP.
0117 220000   E    174        SHLD   ITEMP
011A 210000   E    175 DECKS: LXI    H,     RAMPT   ; RAMPT = RAMPT - 1.
011D 35            176        DCR    M
011E 3A0000   E    177        LDA    NCNT
0121 87            178        ADD    A              ; NOW DO TIMSUM = TIMSUM - R(N)
0122 47            179        MOV    B,     A
0123 3A0000   E    180        LDA    OFFSET
0126 80            181        ADD    B              ; A = 2(NCNT) + OFFSET
0127 0600          182        MVI    B,     00H
0129 4F            183        MOV    C,     A
012A 210000   E    184        LXI    H,     IRBRAM
012D 09            185        DAD    B              ; HL = IRBRAM + OFFSET +2(NCNT)
012E CD0000   E    186        CALL   INVERT
0131 0F            187        RRC
0132 47            188 SUBBS: MOV    B,     A       ; NOW DO ACTUAL SUBTRACTION.
0133 2A0000   E    189        LHLD   TIMSUM
0136 7D            190        MOV    A,     L
0137 98            191        SBB    B
0138 6F            192        MOV    L,     A       ; UPDATE L WITH RESULT.
0139 D24101   C    193        JNC    OUTIT
013C 7C            194        MOV    A,     H       ; NOW DO HOB'S.
013D 0600          195        MVI    B,     00H
013F 98            196        SBB    B
0140 67            197        MOV    H,     A       ; UPDATE H WITH RESULT.
0141 220000   E    198 OUTIT: SHLD   TIMSUM    .    ; TIMSUM = 0 ?????
0144 FE00          199        CPI    00H            ; RECALL A = HOB OF TIMSUM.
0146 C20000   E    200        JNZ    SHOW
0149 7D            201        MOV    A,     L
014A FE00          202        CPI    00H
014C CAB500   C    203        JZ     NMDATA
014F C30000   E    204        JMP    SHOW
0152 3E16          205 PRINT: MVI    A,     16H           ; SELECT 4 EXTRA DOT ROWS OF SPACE.
0154 CD0000   E    206        CALL   PSEND
0157 3E04          207        MVI    A,     04H
0159 CD0000   E    208        CALL   PSEND
015C 218903   C    209        LXI    H,     PRONUM  ; PRINT " PROCESSX(DEB).
015F 0E0A          210        MVI    C,     0AH
0161 CD0000   E    211        CALL   PWRITE
0164 3A0000   E    212        LDA    DEB
0167 C630          213        ADI    30H            ; CONVERT PROCESS NUMBER TO ASCII.
0169 CD0000   E    214        CALL   PSEND
016C 219103   C    215        LXI    H,     TPAST   ; LOAD NOW " XXXTIMEXELASPEDX:X "
```

```
LOC  OBJ          LINE        SOURCE STATEMENT

016F 0E11          216         MVI     C,      11H
0171 CD0000   E    217         CALL    PWRITE
0174 210000   E    218         LXI     H,      COMM1    ; LOAD CONTROL DISPLAY COMMAND ADDRESS.
0177 3671          219         MVI     M,      71H      ; GET MINUTES ELASPED.
0179 210000   E    220         LXI     H,      DATA1
017C 7E            221         MOV     A,      M
017D E5            222         PUSH    H                ; SAVE DATA ADDRESS.
017E CD2603   C    223         CALL    REVERT           ; CHANGE CONTROL DISPLAY CODE TO BCD.
0181 79            224         MOV     A,      C
0182 C630          225         ADI     30H              ; CONVERT TO ASCII.
0184 CD0000   E    226         CALL    PSEND            ; SEND TO PRINTER BUFFER.
0187 E1            227         POP     H
0188 7E            228         MOV     A,      M        ; GET 1'S PLACE MINUTE COUNT.
0189 E5            229         PUSH    H
018A CD2603   C    230         CALL    REVERT
018D 79            231         MOV     A,      C
018E C630          232         ADI     30H
0190 CD0000   E    233         CALL    PSEND
0193 3E20          234         MVI     A,      20H      ; SPACE
0195 CD0000   E    235         CALL    PSEND
0198 3E6D          236         MVI     A,      6DH      ; M
019A CD0000   E    237         CALL    PSEND
019D 3E69          238         MVI     A,      69H      ; I
019F CD0000   E    239         CALL    PSEND
01A2 3E6E          240         MVI     A,      6EH      ; N
01A4 CD0000   E    241         CALL    PSEND
01A7 E1            242         POP     H
01A8 7E            243         MOV     A,      M        ; GET BLANK BETWEEN MINUTES AND SECONDS.
01A9 3E20          244         MVI     A,      20H
01AB CD0000   E    245         CALL    PSEND            ; SEND BLANK TO PRINT BUFFER.
01AE 7E            246         MOV     A,      M        ; GET 10'S PLACE SECOND COUNT.
01AF E5            247         PUSH    H
01B0 CD2603   C    248         CALL    REVERT
01B3 79            249         MOV     A,      C
01B4 C630          250         ADI     30H
01B6 CD0000   E    251         CALL    PSEND
01B9 E1            252         POP     H
01BA 7E            253         MOV     A,      M        ; GET 1'S PLACE SECOND COUNT.
01BB CD2603   C    254         CALL    REVERT
01BE 79            255         MOV     A,      C
01BF C630          256         ADI     30H
01C1 CD0000   E    257         CALL    PSEND
01C4 3E20          258         MVI     A,      20H
01C6 CD0000   E    259         CALL    PSEND            ; SEND BLANK.
01C9 3E73          260         MVI     A,      73H      ; S
01CB CD0000   E    261         CALL    PSEND
01CE 3E65          262         MVI     A,      65H      ; E
01D0 CD0000   E    263         CALL    PSEND
01D3 3E63          264         MVI     A,      63H      ; C
01D5 CD0000   E    265         CALL    PSEND
01D8 3E17          266         MVI     A,      17H      ; PRINT LINE BUFFER CONTENTS.
01DA CD0000   E    267         CALL    PSEND
01DD 3E01          268         MVI     A,      01H      ; INITIALIZE STEP COUNTER.
01DF 320200   D    269         STA     STEP
```

```
 LOC  OBJ         LINE        SOURCE STATEMENT

 01E2 AF           270         XRA    A
 01E3 320000   E   271         STA    TDSTOR          ; SET MSD OF STEP 1 = 0
 01E6 210000   E   272         LXI    H,      COMM2
 01E9 3670         273         MVI    M,      70H     ; SET FOR RAM READ AT 000  (AI) .
 01EB 210000   E   274         LXI    H,      DATA2
 01EE 7E           275         MOV    A,      M       ; READ POSITION 000.
 01EF 1F           276         RAR
 01F0 1F           277         RAR
 01F1 1F           278         RAR
 01F2 1F           279         RAR
 01F3 E60F         280         ANI    0FH
 01F5 320100   E   281         STA    TDSTOR+1
 01F8 7E           282         MOV    A,      M
 01F9 1F           283         RAR
 01FA 1F           284         RAR
 01FB 1F           285         RAR
 01FC 1F           286         RAR
 01FD E60F         287         ANI    0FH
 01FF 320200   E   288         STA    TDSTOR+2
 0202 CD8F02   C   289 FIRST:  CALL   DATPRT          ; PRINT 1ST STEP ON PRINTER.
 0205 210000   E   290         LXI    H,      DATA2
 0208 CD6B02   C   291         CALL   LOADA           ; 3RD.
 020B CD6B02   C   292         CALL   LOADA           ; 5TH.
 020E CD6B02   C   293         CALL   LOADA           ; 7TH.
 0211 CD6B02   C   294         CALL   LOADA           ; 9TH.
 0214 7E           295 SECB:   MOV    A,      M       ; GET 11TH STEP AND CHANGE OVER TO SECTION B.
 0215 1F           296         RAR
 0216 1F           297         RAR
 0217 1F           298         RAR
 0218 1F           299         RAR
 0219 E60F         300         ANI    0FH
 021B 320000   E   301         STA    TDSTOR
 021E 7E           302         MOV    A,      M
 021F 1F           303         RAR
 0220 1F           304         RAR
 0221 1F           305         RAR
 0222 1F           306         RAR
 0223 E60F         307         ANI    0FH
 0225 320100   E   308         STA    TDSTOR+1
 0228 210000   E   309         LXI    H,      COMM2
 022B 3670         310         MVI    M,      70H
 022D 210000   E   311         LXI    H,      DATA2
 0230 7E           312         MOV    A,      M       ; SECTION B, RAM ADDRESS 000
 0231 E60F         313         ANI    0FH
 0233 320200   E   314         STA    TDSTOR+2
 0236 CD8F02   C   315         CALL   DATPRT          ; PRINT 11TH STEP.
 0239 210000   E   316 REST:   LXI    H,      DATA2
 023C CD5302   C   317         CALL   LOADB           ; 13TH.
 023F CD5302   C   318         CALL   LOADB           ; 15TH.
 0242 CD5302   C   319         CALL   LOADB           ; 17TH
 0245 CD5302   C   320         CALL   LOADB           ; 19TH.
 0248 CD5302   C   321         CALL   LOADB           ; 21ST.
 024B 3E17         322         MVI    A,      17H     ; PRINT ONE BLANK LINE TO SEPERATE DATA BLOCKS.
 024D CD0000   E   323         CALL   PSEND
```

```
 LOC  OBJ         LINE        SOURCE STATEMENT

0250 C30000   C   324         JMP     UPORDN
                  325 ;
                  326 ;*********************************************************************
                  327 ;
                  328 ;   ***  LOADB ***
                  329 ;
                  330 ;       READS 3 DISPLAY LOCATIONS FROM DENSITY DISPLAY, STORES THEM
                  331 ;       IN TDSTOR,+1,+2 AND THEN PRINTS IT BY CALLING DATPRTR.
                  332 ;
                  333 ;*********************************************************************
                  334 ;
0253 7E           335 LOADB:  MOV     A,     M        ; ASSUME HL IS LOADED WITH DATA2 ADDRESS.
0254 E60F         336         ANI     0FB
0256 320000   E   337         STA     TDSTOR
0259 7E           338         MOV     A,     M
025A E60F         339         ANI     0FH
025C 320100   E   340         STA     TDSTOR+1
025F 7E           341         MOV     A,     M
0260 E60F         342         ANI     0FH
0262 320200   E   343         STA     TDSTOR+2
0265 E5           344         PUSH    H                ; SAVE CONTENTS OF HL.
0266 CD8F02   C   345         CALL    DATPRT
0269 E1           346         POP     H
026A C9           347         RET
                  348 ;
                  349 ;*********************************************************************
                  350 ;
                  351 ;   ***  LOADA  ***
                  352 ;
                  353 ;       READS 3 DISPLAY LOCATIONS, BUT THIS TIME FROM SECTION B AND MUST
                  354 ;       ROTATE RESULTS 4 TIMES TO GET HON IN LON POSITION.
                  355 ;
                  356 ;*********************************************************************
                  357 ;
026B 7E           358 LOADA:  MOV     A,     M        ; AGAIN ASSUMES HL CONTAINS DATA2 ADDRESS.
026C 1F           359         RAR
026D 1F           360         RAR
026E 1F           361         RAR
026F 1F           362         RAR
0270 E60F         363         ANI     0FH              ; MASK OUT HI-ORDER NIBBLE.
0272 320000   E   364         STA     TDSTOR
0275 7E           365         MOV     A,     M
0276 1F           366         RAR
0277 1F           367         RAR
0278 1F           368         RAR
0279 1F           369         RAR
027A E60F         370         ANI     0FH
027C 320100   E   371         STA     TDSTOR+1
027F 7E           372         MOV     A,     M
0280 1F           373         RAR
0281 1F           374         RAR
0282 1F           375         RAR
0283 1F           376         RAR
0284 E60F         377         ANI     0FH
```

```
  LOC  OBJ         LINE        SOURCE STATEMENT

 0286 320200   E   378              STA     TDSTOR+2
 0289 E5           379              PUSH    H
 028A CD8F02   C   380              CALL    DATPRT
 028D E1           381              POP     H
 028E C9           382              RET
                   383 ;
                   384 ;**************************************************************************
                   385 ;
                   386 ;     ***  DATPRT  ***
                   387 ;
                   388 ;            PASSED:  STEP, TDSTOR,+1,+2 ALL ARE IN BCD.
                   389 ;            STEP IS INCREMENTED BY 2 WHEN EXITED.
                   390 ;
                   391 ;            PRINTS: " STEP (STEP) = (TDSTOR).(+1)(+2) "
                   392 ;
                   393 ;**************************************************************************
                   394 ;
 028F 217F03   C   395 DATPRT: LXI     H,      STEPM    ; SEND XXXXXSTEPXX TO PRINTER.
 0292 0E0B         396         MVI     C,      0BH      ; LOAD TEXT COUNTER.
 0294 CD0000   E   397         CALL    PWRITE
 0297 3A0200   D   398         LDA     STEP             ; STEP IS IN FORMAT: HON = 10'S, LON = 1'S.
 029A 47           399         MOV     B,      A
 029B E60F         400         ANI     0FH              ; MASK TO GET ONE'S PLACE.
 029D FE0B         401         CPI     0BH
 029F C2A902   C   402         JNZ     DONOT            ; IF NO ZERO, THEN 1'S = 9 OR LESS.
 02A2 3E10         403         MVI     A,      10H      ; SET A = 00010000B
 02A4 80           404         ADD     B                ; INCREMENT 10'S PLACE
 02A5 E6F0         405         ANI     0F0H             ; RESET ONE'S PLACE TO ZERO.
 02A7 3C           406         INR     A                ; ADD 1 TO GET FROM 10D TO 11D.
 02A8 47           407         MOV     B,      A
 02A9 78           408 DONOT:  MOV     A,      B
 02AA 320200   D   409         STA     STEP             ; UPDATE STEP.
 02AD 1F           410         RAR
 02AE 1F           411         RAR
 02AF 1F           412         RAR
 02B0 1F           413         RAR                      ; ROTATE TO GET 10'S PLACE INTO LON.
 02B1 E60F         414         ANI     0FH              ; SET HON=0.
 02B3 C630         415         ADI     30H              ; CONVERT TO ASCII.
 02B5 CD0000   E   416         CALL    PSEND            ; SEND TO PRINTER.
 02B8 78           417         MOV     A,      B
 02B9 E60F         418         ANI     0FH
 02BB C630         419         ADI     30H
 02BD CD0000   E   420         CALL    PSEND
 02C0 3E20         421         MVI     A,      20H      ; SEND BLANK TO PRINTER.
 02C2 CD0000   E   422         CALL    PSEND
 02C5 3E3D         423         MVI     A,      3DH      ; SEND EQUAL SIGN (=).
 02C7 CD0000   E   424         CALL    PSEND
 02CA 3E20         425         MVI     A,      20H      ; SEND ONE MORE SPACE.
 02CC CD0000   E   426         CALL    PSEND
 02CF 3A0000   E   427         LDA     TDSTOR           ; GET MOST SIGNIFICANT DENSITY DIGIT.
 02D2 C630         428         ADI     30H              ; CONVERT TO ASCII.
 02D4 CD0000   E   429         CALL    PSEND
 02D7 3E2E         430         MVI     A,      2EH      ; SEND " . " TO PRINTER BUFFER.
 02D9 CD0000   E   431         CALL    PSEND
```

```
 LOC  OBJ         LINE        SOURCE STATEMENT

 02DC 3A0100   E   432          LDA     TDSTOR+1
 02DF C630         433          ADI     30H
 02E1 CD0000   E   434          CALL    PSEND
 02E4 3A0200   E   435          LDA     TDSTOR+2
 02E7 C630         436          ADI     30H
 02E9 CD0000   E   437          CALL    PSEND
 02EC 3E17         438          MVI     A,      17H
 02EE CD0000   E   439          CALL    PSEND            ; NOW PRINT BUFFER CONTENTS.
 02F1 210200   D   440          LXI     H,      STEP
 02F4 3E02         441          MVI     A,      02H
 02F6 86           442          ADD     M
 02F7 77           443          MOV     M,      A
 02F8 C9           444          RET
                   445 ;
                   446 ;        A SIMPLE SURROUTINE FOR THOSE OF YOU WHO ARE RUBBER PEOPLE.
                   447 ;
 02F9 3E00         448 RESET:   MVI     A,      00H     ; RESET MANFLG TO OFF.
 02FB 320000   E   449          STA     MANFLG
 02FE 212C80       450          LXI     H,      802CH   ; RESET DRAM POINTER.
 0301 220000   E   451          SHLD    MXDRAM
 0304 3E93         452          MVI     A,      93H
 0306 320000   E   453          STA     POS1
 0309 3E04         454          MVI     A,      04H
 030B 320000   E   455          STA     POS2
 030E 3E64         456          MVI     A,      64H
 0310 320000   E   457          STA     RPOS1
 0313 3EDF         458          MVI     A,      0DFH
 0315 320000   E   459          STA     CLEARA
 0318 320000   E   460          STA     CLEARB
 031B 3E16         461          MVI     A,      16H     ; RESET PRINTER TO 0 EXTRA DOT FEED.
 031D CD0000   E   462          CALL    PSEND
 0320 3E00         463          MVI     A,      00H
 0322 CD0000   E   464          CALL    PSEND
 0325 C9           465          RET
                   466 ;
                   467 ;*******************************************************************
                   468 ;
                   469 ;   ***  REVERT  ***
                   470 ;
                   471 ;        REVERT RECEIVES CONTROL DISPLAY CODE IN A REGISTER AND CONVERTS
                   472 ;        IT TO THE EQUIVALENT BCD CODE AND RETURNS IT IN C REGISTER.
                   473 ;
                   474 ;*******************************************************************
                   475 ;
 0326 FE0C         476 REVERT:  CPI     0CH             ; DISPLAY CODE FOR ZERO.
 0328 0E00         477          MVI     C,      00H     ; 00H
 032A C8           478          RZ
 032B FE9F         479          CPI     9FH             ; 01
 032D 0E01         480          MVI     C,      01H     ; 01
 032F C8           481          RZ
 0330 FE4A         482          CPI     4AH             ; 02
 0332 0E02         483          MVI     C,      02H     ; 02
 0334 C8           484          RZ
 0335 FE0B         485          CPI     0BH             ; 03
```

```
LOC  OBJ           SOURCE STATEMENT

0337 0E03                  MVI     C,      03H     ; 03
0339 C8                    RZ
033A FE99                  CPI     99H             ; 04
033C 0E04                  MVI     C,      04H     ; 04
033E C8                    RZ
033F FE29                  CPI     29H             ; 05
0341 0E05                  MVI     C,      05H     ; 05
0343 C8                    RZ
0344 FE28                  CPI     28H             ; 06
0346 0E06                  MVI     C,      06H     ; 06
0348 C8                    RZ
0349 FE0F                  CPI     0FH             ; 07
034B 0E07                  MVI     C,      07H     ; 07
034D C8                    RZ
034E FE08                  CPI     08H             ; 08
0350 0E08                  MVI     C,      08H     ; 08
0352 C8                    RZ
0353 FE09                  CPI     09H             ; 09
0355 0E09                  MVI     C,      09H     ; 09
0357 C8                    RZ
0358 C9                    RET                     ; NO MATCH WILL RWTURN ANY WAY.
                     ;***************************
                     ;
                     ;         ** CLEAN **
                     ;
                     ;         CLEAN ALLOWS MANUAL USE OF FTS SYSTEM SO USER MAY CHANGE SOLUTIONS
                     ;         WITHOUT HAVING TO RE-CALIBRATE DEVICE.  DEVICE WILL REMAIN IN MANUAL
                     ;         MODE UNTIL ENTER KEY IS PRESSED.
                     ;
                     ;****************************
                     ;
0359 210000   E      CLEAN:    LXI     H,      MANMOD  ; PROMPT "MANUAL MODE?"
035C 060D                      MVI     B,      0DB
035E CD0000   E                CALL    DWRITE
0361 CD0000   E                CALL    KDSPY2          ; ENTER 0 AND RETURN TO WARM START.
0364 3A0000   E                LDA     SUM2            ; ANYTHING ELSE PUTS YOU INTO MANUAL.
0367 FE00                      CPI     00H
0369 CA0000   E                JZ      START
036C 3EFE                      MVI     A,      0FEH    ; SET FOR MANUAL CONTROL.
036E D300     E                OUT     LOW RPA2
0370 C35903   C                JMP     CLEAN
                     ;
                     ;         DISPLAY MESSAGES.
                     ;
0373 0E              NMDATM:   DB      0EH     ; N
0374 0F                        DB      0FH     ; O
0375 20                        DB      20H     ; BLANK
0376 0D                        DB      0DH     ; M
0377 0F                        DB      0FH     ; O
0378 12                        DB      12H     ; R
0379 05                        DB      05H     ; E
037A 20                        DB      20H     ; BLANK
037B 04                        DB      04H     ; D
037C 01                        DB      01H     ; A
```

```
  LOC  OBJ         LINE        SOURCE STATEMENT

  037D 14           540          DB      14H      ; T
  037E 01           541          DB      01H      ; A
  037F 20           542 STEPM:   DB      20H      ; SPACE
  0380 20           543          DB      20H      ; SPACE
  0381 20           544          DB      20H      ; SPACE
  0382 20           545          DB      20H      ; SPACE
  0383 20           546          DB      20H      ; SPACE
  0384 53           547          DB      53H      ; S
  0385 74           548          DB      74H      ; T
  0386 65           549          DB      65H      ; E
  0387 70           550          DB      70H      ; P
  0388 20           551          DB      20H      ; SPACE
  0389 50           552 PRONUM:  DB      50H      ; P
  038A 52           553          DB      52H      ; R
  038B 4F           554          DB      4FH      ; O
  038C 43           555          DB      43H      ; C
  038D 45           556          DB      45H      ; E
  038E 53           557          DB      53H      ; S
  038F 53           558          DB      53H      ; S
  0390 20           559          DB      20H      ; SPACE
  0391 20           560 TPAST:   DB      20H      ; SPACE
  0392 20           561          DB      20H      ; SPACE
  0393 20           562          DB      20H      ; SPACE
  0394 54           563          DB      54H      ; T
  0395 69           564          DB      69H      ; I
  0396 6D           565          DB      6DH      ; M
  0397 65           566          DB      65H      ; E
  0398 20           567          DB      20H      ; SPACE
  0399 45           568          DB      45H      ; E
  039A 6C           569          DB      6CH      ; L
  039B 61           570          DB      61H      ; A
  039C 73           571          DB      73H      ; S
  039D 70           572          DB      70H      ; P
  039E 65           573          DB      65H      ; E
  039F 64           574          DB      64H      ; D
  03A0 20           575          DB      20H      ; SPACE
  03A1 3A           576          DB      3AH      ; :
  03A2 20           577          DB      20H      ; SPACE
                    578 ;
                    579          DSEG
                    580 ;
  0000              581 LITEMP:  DS      02H      ; 2 BYTES OF RAM FOR LOWER INTERVAL STORAGE IN NEXTDN.
  0002              582 STEP:    DS      01H      ; 1 BYTE USED AS STEP COUNTER IN PRINT ROUTINE.
                    583 ;
                    584          END


PUBLIC SYMBOLS
UPORDN C 0000

EXTERNAL SYMBOLS
CLEARA E 0000   CLEARB E 0000   COMM1  E 0000   COMM2  E 0000   DATA1  E 0000   DATA2  E 0000   DEB    E 0000
DFIND  E 0000   DRAM   E 0000   DWRITE E 0000   FIFOCR E 0000   INVERT E 0000   IRBRAM E 0000   IRCNT  E 0000
ITEMP  E 0000   KDSPY2 E 0000   MANFLG E 0000   MANMOD E 0000   MIN    E 0000   MINCON E 0000   NCNT   E 0000
```

```
NXDRAM E 0000   OFFSET E 0000   POS1   E 0000   POS2   E 0000   PSEND  E 0000   PWRITE E 0000   RAMPT  E 0000
RPA2   E 0000   RPOS1  E 0000   SHOW   E 0000   START  E 0000   SUM2   E 0000   TDSTOR E 0000   TIMSUM E 0000

USER SYMBOLS
CLEAN  C 0359   CLEARA E 0000   CLEARB E 0000   COMM1  E 0000   COMM2  E 0000   DATA1  E 0000   DATA2  E 0000
DATPRT C 028F   DEB    E 0000   DECKS  C 011A   DFIND  E 0000   DONE   C 00DF   DONOT  C 02A9   DRAM   E 0000
EWRITE E 0000   FIFOCR E 0000   FIRST  C 0202   INKN   C 0083   INVERT E 0000   IRBRAM E 0000   IRCNT  E 0000
ITEMP  E 0000   KDSPY2 E 0000   KLOOK  C 0006   LITEMP D 0000   LOADA  C 026B   LOADB  C 0253   MANFLG E 0000
MANMOD E 0000   MIN    E 0000   MINCON E 0000   NCNT   E 0000   NEKEY  C 002D   NEQ0   C 0108   NEXTDN C 00C0
NEXTUP C 004A   NMDATA C 00B5   NMDATM C 0373   NOBARO C 00D8   NOTEQ  C 005B   NXDRAM E 0000   OFFSET E 0000
OMT    C 00C8   OUTIT  C 0141   POS1   E 0000   POS2   E 0000   PRINT  C 0152   PRONUM C 0389   PSEND  E 0000
PWRITE E 0000   RAMPT  E 0000   RESET  C 02F9   REST   C 0239   REVERT C 0326   RPA2   E 0000   RPOS1  E 0000
SECB   C 0214   SHOW   E 0000   START  E 0000   STEP   D 0002   STEPM  C 037F   SUBBS  C 0132   SUM2   E 0000
TDSTOR E 0000   TIMSUM E 0000   TPAST  C 0391   UPORDN C 0000

ASSEMBLY COMPLETE,   NO ERRORS
```

Appendix 3: Raw Data

The first section of data that appears here is for EK Commercial Film, type 6127 developed in D-76. The raw data is reproduced directly from the printer tapes that are output by the IR densitometer. After this first set was collected, the electronics that control the printer broke down and the unit had to be returned to the manufacturer for repair. The remaining data from the Fine Grain Release Positive experiments was reproduced by hand from the 33-digit LED density display. The IR densitometer will still work without the printer, but it certainly saves a lot of work for the user.

At the time of this writing, the control electronics still had not yet been returned from the NCR Corporation.

```
*************************************
      Process 1 =  05 minutes
*************************************
```

Run 1   12/10/81

```
   Interval  01 = 01 minutes
       Rate  01 = 60 scans/minute

   Interval  02 = 04 minutes
       Rate  02 = 10 scans/minute

*************************************
      Process 2 =  01 minutes
*************************************

*************************************
      Process 3 =  00 minutes
*************************************
```

PROCESS 1 Time Elasped 00 min 19 sec

Step 01 = 0.21
Step 03 = 0.21
Step 05 = 0.20
Step 07 = 0.22
Step 09 = 0.22
Step 11 = 0.22
Step 13 = 0.22
Step 15 = 0.22
Step 17 = 0.21
Step 19 = 0.23
Step 21 = 0.22

PROCESS 1 Time Elasped 00 min 23 sec

Step 01 = 0.20
Step 03 = 0.20
Step 05 = 0.20
Step 07 = 0.21
Step 09 = 0.21
Step 11 = 0.22
Step 13 = 0.21
Step 15 = 0.22
Step 17 = 0.21
Step 19 = 0.23
Step 21 = 0.23

PROCESS 1 Time Elasped 00 min 50 sec

Step 01 = 0.19
Step 03 = 0.19
Step 05 = 0.19
Step 07 = 0.22
Step 09 = 0.23
Step 11 = 0.28
Step 13 = 0.33
Step 15 = 0.41
Step 17 = 0.51
Step 19 = 0.64
Step 21 = 0.75

PROCESS 1 Time Elasped 01 min 30 sec

Step 01 = 0.19
Step 03 = 0.19
Step 05 = 0.22
Step 07 = 0.30
Step 09 = 0.40
Step 11 = 0.53
Step 13 = 0.68
Step 15 = 0.86
Step 17 = 1.06
Step 19 = 1.31
Step 21 = 1.51

PROCESS 1 Time Elasped 02 min 00 sec

Step 01 = 0.19
Step 03 = 0.21
Step 05 = 0.26
Step 07 = 0.39
Step 09 = 0.53
Step 11 = 0.71
Step 13 = 0.90
Step 15 = 1.13
Step 17 = 1.38
Step 19 = 1.68
Step 21 = 1.96

PROCESS 1 Time Elasped 02 min 30 sec

Step 01	0.19
Step 03	0.22
Step 05	0.30
Step 07	0.46
Step 09	0.64
Step 11	0.86
Step 13	1.08
Step 15	1.33
Step 17	1.62
Step 19	1.98
Step 21	2.38

PROCESS 1 Time Elasped 03 min 00 sec

Step 01	0.19
Step 03	0.23
Step 05	0.33
Step 07	0.53
Step 09	0.74
Step 11	0.98
Step 13	1.22
Step 15	1.50
Step 17	1.81
Step 19	2.22
Step 21	3.00

PROCESS 1 Time Elasped 04 min 00 sec

Step 01	0.19
Step 03	0.24
Step 05	0.24
Step 07	0.64
Step 09	0.90
Step 11	1.16
Step 13	1.44
Step 15	1.72
Step 17	2.09
Step 19	2.66
Step 21	3.76

PROCESS 1 Time Elasped 05 min 00 sec

Step 01	0.21
Step 03	0.26
Step 05	0.41
Step 07	0.69
Step 09	0.99
Step 11	1.28
Step 13	1.58
Step 15	1.88
Step 17	2.31
Step 19	3.32
Step 21	3.76

```
*************************************
      Process 1 =  05 minutes
*************************************
```

Run 2 12/10/81

```
   Interval  01 = 01 minutes
      Rate  01 = 60 scans/minute

   Interval  02 = 04 minutes
      Rate  02 = 10 scans/minute

*************************************
      Process 2 =  01 minutes
*************************************

*************************************
      Process 3 =  00 minutes
*************************************
```

PROCESS 1 Time Elasped 00 min 19 sec

Step 01	0.19
Step 03	0.19
Step 05	0.20
Step 07	0.21
Step 09	0.20
Step 11	0.20
Step 13	0.20
Step 15	0.20
Step 17	0.19
Step 19	0.21
Step 21	0.21

PROCESS 1 Time Elasped 00 min 23 sec

Step 01	0.19
Step 03	0.19
Step 05	0.19
Step 07	0.20
Step 09	0.20
Step 11	0.20
Step 13	0.20
Step 15	0.20
Step 17	0.19
Step 19	0.23
Step 21	0.23

PROCESS 1 Time Elasped 00 min 50 sec

Step 01	0.18
Step 03	0.18
Step 05	0.19
Step 07	0.20
Step 09	0.22
Step 11	0.26
Step 13	0.33
Step 15	0.41
Step 17	0.52
Step 19	0.67
Step 21	0.77

PROCESS 1 Time Elasped 01 min 30 sec

Step 01	0.18
Step 03	0.19
Step 05	0.22
Step 07	0.29
Step 09	0.39
Step 11	0.53
Step 13	0.68
Step 15	0.86
Step 17	1.07
Step 19	1.33
Step 21	1.53

PROCESS 1 Time Elasped 02 min 00 sec

Step 01	0.18
Step 03	0.19
Step 05	0.26
Step 07	0.37
Step 09	0.52
Step 11	0.70
Step 13	0.89
Step 15	1.13
Step 17	1.38
Step 19	1.69
Step 21	1.97

PROCESS 1 Time Elasped 02 min 30 sec

Step 01 = 0.18
Step 03 = 0.21
Step 05 = 0.30
Step 07 = 0.45
Step 09 = 0.63
Step 11 = 0.85
Step 13 = 1.08
Step 15 = 1.33
Step 17 = 1.62
Step 19 = 1.99
Step 21 = 2.39

PROCESS 1 Time Elasped 03 min 00 sec

Step 01 = 0.18
Step 03 = 0.22
Step 05 = 0.33
Step 07 = 0.51
Step 09 = 0.73
Step 11 = 0.97
Step 13 = 1.21
Step 15 = 1.49
Step 17 = 1.81
Step 19 = 2.24
Step 21 = 2.98

PROCESS 1 Time Elasped 04 min 00 sec

Step 01 = 0.19
Step 03 = 0.24
Step 05 = 0.39
Step 07 = 0.62
Step 09 = 0.88
Step 11 = 1.16
Step 13 = 1.43
Step 15 = 1.72
Step 17 = 2.09
Step 19 = 2.67
Step 21 = 3.76

PROCESS 1 Time Elasped 05 min 00 sec

Step 01 = 0.20
Step 03 = 0.26
Step 05 = 0.41
Step 07 = 0.68
Step 09 = 0.98
Step 11 = 1.27
Step 13 = 1.55
Step 15 = 1.87
Step 17 = 2.30
Step 19 = 3.75
Step 21 = 3.76

****
Process 1 = 05 minutes
****

Run 3 12/10/81

Interval 01 = 01 minutes
Rate 01 = 60 scans/minute

Interval 02 = 04 minutes
Rate 02 = 10 scans/minute

****
Process 2 = 01 minutes
****

****
Process 3 = 00 minutes
****

PROCESS 1 Time Elasped 00 min 19 sec

Step 01 = 0.21
Step 03 = 0.21
Step 05 = 0.21
Step 07 = 0.21
Step 09 = 0.22
Step 11 = 0.22
Step 13 = 0.22
Step 15 = 0.22
Step 17 = 0.22
Step 19 = 0.23
Step 21 = 0.23

PROCESS 1 Time Elasped 00 min 23 sec

Step 01 = 0.20
Step 03 = 0.21
Step 05 = 0.20
Step 07 = 0.21
Step 09 = 0.21
Step 11 = 0.22
Step 13 = 0.21
Step 15 = 0.22
Step 17 = 0.22
Step 19 = 0.24
Step 21 = 0.26

PROCESS 1 Time Elasped 00 min 50 sec

Step 01 = 0.19
Step 03 = 0.19
Step 05 = 0.19
Step 07 = 0.21
Step 09 = 0.24
Step 11 = 0.29
Step 13 = 0.35
Step 15 = 0.44
Step 17 = 0.55
Step 19 = 0.69
Step 21 = 0.81

PROCESS 1 Time Elasped 01 min 30 sec

Step 01 = 0.19
Step 03 = 0.19
Step 05 = 0.22
Step 07 = 0.30
Step 09 = 0.41
Step 11 = 0.55
Step 13 = 0.71
Step 15 = 0.90
Step 17 = 1.11
Step 19 = 1.35
Step 21 = 1.59

PROCESS 1 Time Elasped 02 min 00 sec

Step 01 = 0.19
Step 03 = 0.21
Step 05 = 0.26
Step 07 = 0.38
Step 09 = 0.54
Step 11 = 0.73
Step 13 = 0.93
Step 15 = 1.16
Step 17 = 1.42
Step 19 = 1.73
Step 21 = 2.03

PROCESS 1 Time Elasped 02 min 30 sec

Step 01 = 0.19
Step 03 = 0.22
Step 05 = 0.31
Step 07 = 0.46
Step 09 = 0.65
Step 11 = 0.87
Step 13 = 1.11
Step 15 = 1.37
Step 17 = 1.65
Step 19 = 2.02
Step 21 = 2.46

PROCESS 1 Time Elasped 03 min 00 sec

Step 01 = 0.19
Step 03 = 0.23
Step 05 = 0.33
Step 07 = 0.53
Step 09 = 0.75
Step 11 = 1.00
Step 13 = 1.24
Step 15 = 1.52
Step 17 = 1.84
Step 19 = 2.27
Step 21 = 3.23

PROCESS 1 Time Elasped 04 min 00 sec

Step 01 = 0.19
Step 03 = 0.24
Step 05 = 0.39
Step 07 = 0.64
Step 09 = 0.90
Step 11 = 1.18
Step 13 = 1.45
Step 15 = 1.74
Step 17 = 2.12
Step 19 = 2.69
Step 21 = 3.76

PROCESS 1 Time Elasped 05 min 00 sec

Step 01 = 0.21
Step 03 = 0.26
Step 05 = 0.41
Step 07 = 0.69
Step 09 = 0.99
Step 11 = 1.29
Step 13 = 1.58
Step 15 = 1.89
Step 17 = 2.33
Step 19 = 3.49
Step 21 = 3.76

Fine Grain Release Positive in D-19. 1/29/82
Temp: 70°F
Filter: 1.20 N.D.
Sensitometer current = .82 amp
Calibration Standard: .70

Time:

①

7 sec	14	30	45	60	1:30	2	3	4	5
.14	.16	.17	.17	.17	.17	.19	.23	.27	.32
.14	.17	.17	.17	.18	.18	.20	.24	.28	.33
.14	.17	.18	.18	.18	.18	.20	.24	.28	.33
.16	.19	.19	.19	.19	.20	.22	.26	.31	.36
.16	.19	.20	.20	.20	.22	.24	.28	.34	.40
.16	.19	.20	.22	.24	.26	.29	.37	.44	.51
.14	.18	.24	.28	.32	.39	.46	.58	.72	.84
.16	.22	.38	.48	.57	.74	.87	1.12	1.32	1.49
.19	.32	.64	.85	1.00	1.25	1.47	1.81	2.08	2.27
.18	.41	.91	1.27	1.50	1.87	2.15	2.52	2.74	2.94
.20	.53	1.17	1.65	1.93	2.35	2.60	2.94	3.14	3.08

②

.13	.16	.17	.17	.16	.17	.18	.21	.25	.30
.13	.16	.16	.16	.16	.16	.17	.21	.25	.30
.13	.17	.18	.18	.17	.18	.19	.23	.27	.31
.14	.19	.19	.19	.19	.19	.21	.25	.29	.34
.14	.17	.18	.19	.19	.20	.22	.26	.31	.36
.17	.22	.23	.24	.25	.28	.31	.37	.44	.51
.14	.19	.25	.28	.32	.39	.45	.58	.70	.80
.17	.26	.39	.49	.58	.72	.86	1.07	1.26	1.43
.18	.33	.59	.80	.95	1.21	1.42	1.76	2.03	2.24
.18	.44	.86	1.22	1.44	1.80	2.09	2.50	2.75	2.90
.19	.53	1.10	1.58	1.87	2.28	2.56	2.85	2.98	3.06

F.G.R.P. in D-19 (Con't) 1/29

(3) Time:

7sec	14	30	45	60	1:30	2	3	4	5
.13	.16	.17	.17	.17	.17	.19	.22	.27	.33
.13	.16	.18	.17	.17	.17	.19	.24	.28	.33
.13	.16	.17	.17	.17	.17	.19	.23	.28	.33
.14	.18	.19	.19	.19	.20	.22	.26	.31	.36
.14	.18	.19	.20	.20	.21	.23	.28	.34	.40
.15	.19	.21	.22	.24	.26	.30	.37	.44	.51
.16	.22	.28	.32	.36	.43	.50	.63	.76	.87
.17	.25	.41	.51	.60	.75	.89	1.13	1.32	1.50
.14	.29	.60	.82	.98	1.26	1.48	1.83	2.09	2.31
.16	.41	.89	1.26	1.49	1.88	2.17	2.55	2.82	2.93
.19	.53	1.17	1.64	1.93	2.36	2.61	2.97	3.15	3.08

(4) Developer and rinse water <u>not</u> replaced for this last run.

.16	.19	.20	.19	.20	.20	.22	.26	.31	.36
.14	.17	.17	.18	.18	.19	.20	.25	.30	.36
.16	.18	.19	.20	.20	.20	.22	.26	.32	.38
.16	.19	.20	.20	.20	.21	.23	.28	.33	.38
.16	.18	.19	.20	.20	.22	.23	.30	.36	.43
.17	.19	.22	.24	.25	.28	.32	.40	.48	.56
.18	.22	.29	.34	.38	.46	.54	.68	.82	.94
.19	.27	.44	.56	.66	.82	.96	1.23	1.43	1.61
.17	.33	.68	.91	1.08	1.35	1.59	1.94	2.20	2.40
.20	.48	1.05	1.39	1.64	2.02	2.29	2.69	2.92	3.07
.24	.62	1.37	1.81	2.08	2.50	2.75	3.03	3.09	3.12

Fine Grain Release Positive in D-76 1/29/82
Temp: 70°F
Filter: .78 N.D.
Sensitometer Current = .82 amp
Calibration Standard = .70

Time:

(1)

20sec	30	45	1:00	1:30	2	3	4	5
.19	.18	.18	.17	.16	.16	.13	.12	.10
.20	.19	.19	.18	.17	.16	.14	.13	.10
.16	.16	.16	.16	.15	.14	.13	.12	.10
.18	.18	.17	.18	.18	.18	.18	.17	.16
.17	.17	.20	.22	.25	.28	.31	.33	.34
.19	.21	.26	.32	.39	.45	.54	.60	.65
.21	.25	.35	.45	.59	.70	.85	.96	1.05
.20	.28	.44	.60	.81	.96	1.18	1.35	1.48
.25	.37	.60	.79	1.10	1.31	1.59	1.80	1.97
.29	.47	.74	.98	1.37	1.63	2.00	2.25	2.42
.29	.50	.82	1.11	1.54	1.88	2.30	2.58	2.72

(2)

.17	.17	.16	.16	.15	.13	.12	.10	.08
.21	.20	.19	.18	.17	.16	.14	.12	.10
.19	.19	.17	.17	.16	.16	.14	.12	.10
.21	.20	.20	.20	.20	.19	.19	.18	.16
.17	.17	.19	.20	.23	.26	.30	.32	.33
.18	.19	.25	.31	.38	.44	.53	.59	.64
.19	.23	.35	.44	.59	.69	.85	.97	1.07
.24	.32	.48	.63	.83	.98	1.20	1.37	1.50
.27	.39	.62	.81	1.12	1.32	1.60	1.83	1.99
.28	.44	.73	.97	1.37	1.64	2.01	2.28	2.47
.33	.54	.85	1.14	1.57	1.90	2.33	2.59	2.74

F.G.R.P in D-76 (Con't) 1/29

Time:

(3)

20sec	30	45	1:00	1:30	2	3	4	5
.17	.17	.16	.15	.14	.13	.11	.10	.08
.16	.16	.15	.14	.13	.13	.12	.10	.08
.16	.16	.15	.14	.13	.13	.12	.10	.09
.18	.17	.16	.16	.16	.17	.16	.16	.15
.16	.16	.19	.21	.24	.26	.30	.31	.33
.21	.22	.27	.32	.40	.46	.54	.60	.65
.21	.25	.36	.46	.60	.70	.86	.97	1.07
.22	.29	.46	.60	.82	.97	1.19	1.37	1.50
.25	.38	.59	.79	1.10	1.31	1.59	1.82	1.98
.29	.47	.75	.98	1.37	1.65	2.02	2.27	2.46
.30	.51	.83	1.12	1.56	1.90	2.33	2.60	2.80

(4)

Developer and rinse water not Replaced for this last run.

.19	.18	.17	.16	.15	.14	.12	.10	.09
.19	.19	.17	.17	.16	.15	.13	.12	.10
.17	.16	.16	.15	.14	.13	.13	.11	.10
.20	.20	.19	.19	.19	.19	.19	.18	.17
.19	.19	.20	.23	.26	.29	.32	.34	.36
.21	.23	.29	.35	.42	.48	.57	.63	.68
.23	.28	.40	.50	.64	.73	.89	1.02	1.11
.25	.35	.52	.67	.88	1.03	1.25	1.42	1.54
.26	.41	.65	.86	1.16	1.36	1.64	1.87	2.02
.30	.50	.79	1.04	1.43	1.70	2.07	2.31	2.50
.33	.58	.91	1.19	1.64	1.97	2.39	2.63	2.85

12/11/81

Dry, fixed out white light density readings Taken on TD-504.

Eastman Kodak Commercial Film developed in D-76 @ 70°F. all readings after 5 minutes of development.

Step\Run	1	2	3
1	.08	.09	.09
2	.12	.12	.12
3	.23	.23	.23
4	.43	.43	.44
5	.71	.71	.71
6	1.02	1.02	1.03
7	1.34	1.33	1.35
8	1.68	1.67	1.68
9	2.02	2.02	2.03
10	2.40	2.42	2.42
11	2.72	2.73	2.73

1/30/82

Dry, fixed out white lite density
Readings taken on TD-504.

Fine Grain Release Positive in D-19:

Step\Run	1	2	3	4
1	.29	.26	.30	.29
2	.29	.27	.30	.30
3	.30	.28	.31	.31
4	.32	.29	.33	.33
5	.35	.33	.36	.37
6	.48	.44	.49	.52
7	.88	.80	.88	.94
8	1.61	1.51	1.61	1.72
9	2.54	2.41	2.55	2.66
10	3.36	3.24	3.36	3.46
11	3.94	3.80	3.91	4.01

Fine Grain Release Positive in D-76:

Step\Run	1	2	3	4
1	.04	.04	.05	.05
2	.04	.05	.05	.06
3	.06	.06	.07	.07
4	.12	.12	.12	.13
5	.29	.29	.29	.32
6	.61	.60	.62	.66
7	1.06	1.05	1.07	1.12
8	1.55	1.54	1.56	1.62
9	2.04	2.04	2.05	2.13
10	2.63	2.61	2.62	2.70
11	3.05	3.03	3.05	3.15

Appendix 4: Infrared Emitting Diode LED55C* Specifications:

Absolute Maximum Ratings (@ 25°C):

Reverse Voltage	V_R	3	volts
Forward Current	I_F	100	mA
Power Dissipation	P_T	170	mW

Optical Characteristics (@ 25°C):

Total Power Output (I_F=100mA)	P_0	5.4	mW
Peak Emmision Wavelength (I_F=100mA)		940	nm
Spectral Bandwidth 50%		60	nm
Rise Time 0-90% of output		300	nsec

* From Optoelectronics Manual, General Electric Company, Electronics Park, Syracuse, N.Y. 13201.

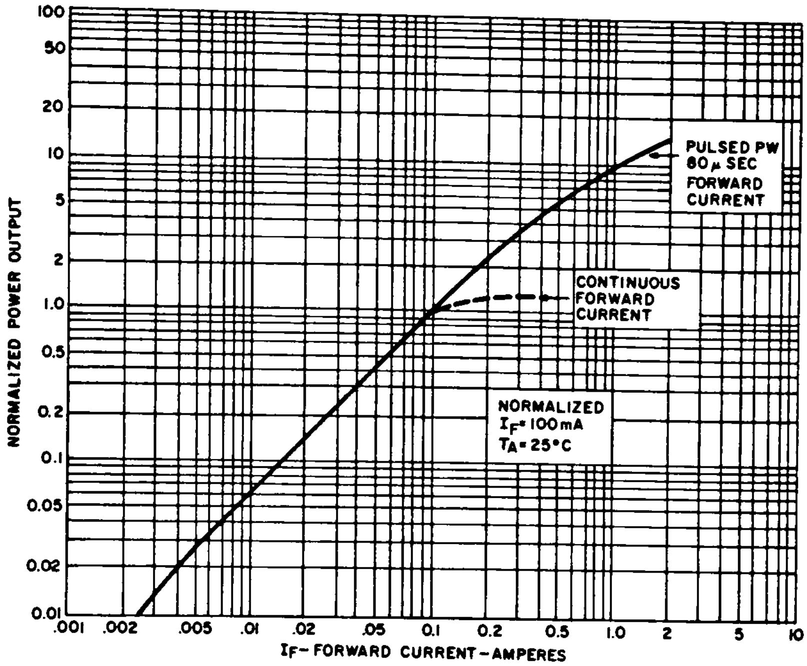

Figure 22: Power Output vs. Input Current for LED55C

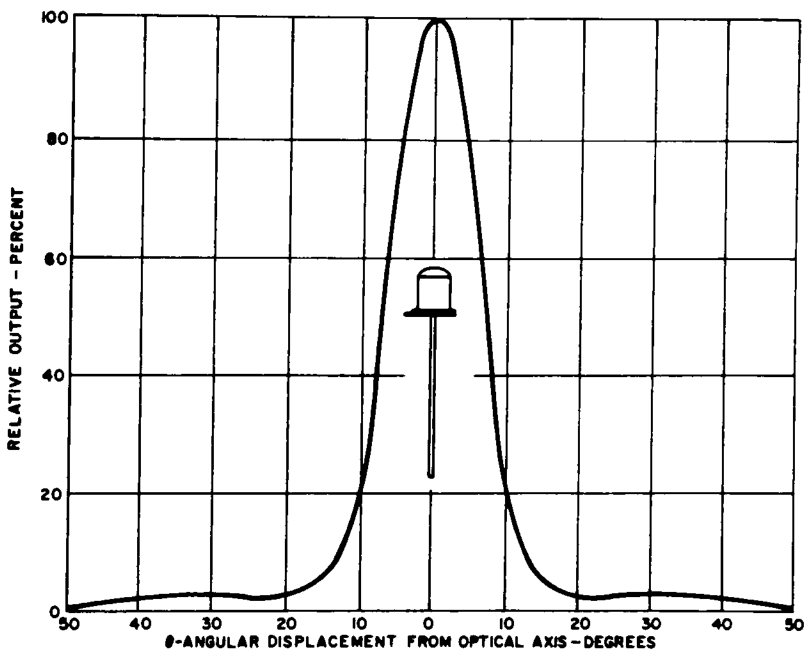

Figure 23: Typical Radiation Pattern for LED55C

Appendix 5: UDT-450 Specifications* :

Parameter	Symbol	Typical Value	Units
Responsivity	R	.4 @850 nm	amp/watt
Active Area	A	.05	cm^2
Active Dia.	D	.10	inch
Output Resistance	Z_{out}	100	ohms
slew Rate		1	volt/microsec
Unit Gain Bandwidth		1	MHz
Supply Voltage		+/-15	volts
Supply Current		3	mA
Offset Voltage Drift w/ Temperature		+/-25	microvolt/•C
Light Range	L	10^{-2}-$5x10^{-12}$	$watts/cm^2$
Feedback resistor Range	R_f	.5K-50M	ohms
Frequency response	f	dc-10^6	Hz
Spectral Range		350-1100	nm

* UDT-450 Data Sheet, United Detector Technology, 2644 30th st. Santa monica, CA. 90405.

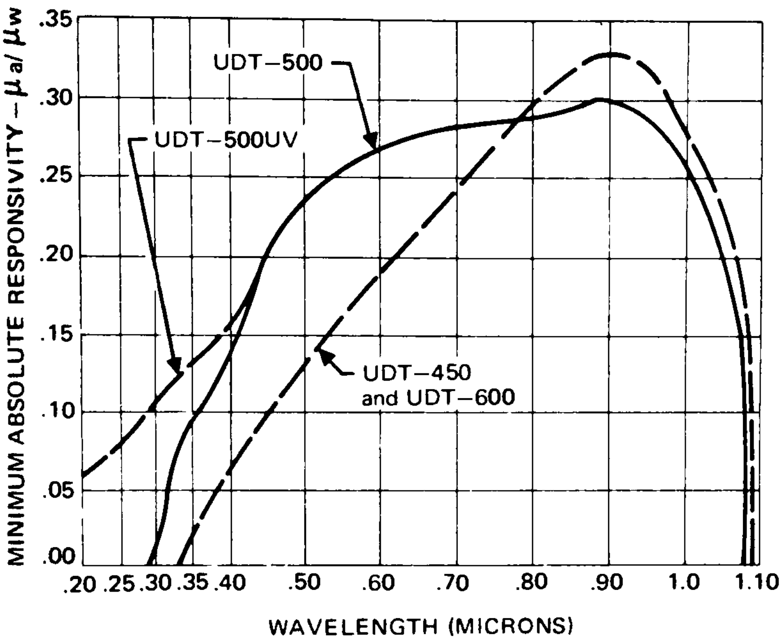

Figure 24: Spectral Response of UDT-450

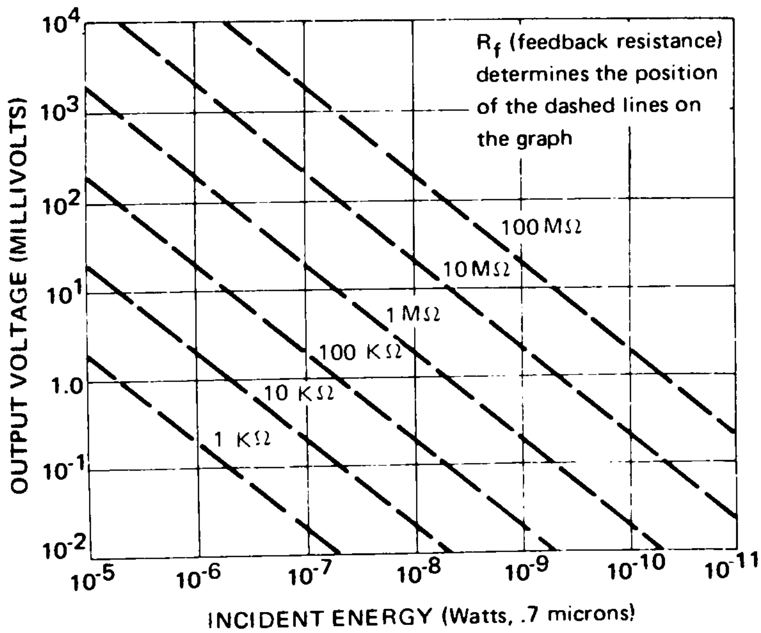

Figure 25: Output voltage of UDT-450 as a function of incident energy

Appendix 6: Model 757N Logarithmic Ratio Amplifier* :

Transfer Function:	
voltage mode	$e_0 = -K\text{Log}_{10}(e_1/e_2 \times R_2/R_1)$
Accuracy:	
log conformity	+/- 1%, max.
1nA to 10mA	Relative to Input
Input Specs:	
maximum current	+/- 10 mA
worst case offset voltage	+/- 85 microvolts/°C max.
Rise Time:	
increasing input	250 microsecond max.
decreasing input	600 microsecond max.
Power Supply:	
rated performance	+/- 15V dc
operating	+/- (12 to 18)V dc
current, quiesent	+/- 8 mA
Mechanical:	
case size	1.5" x 1.5" x 0.4"
weight	21 grams

* Data sheet, Analog Devices, P.O. Box 280, Norwood, Mass. 02062.

Appendix 7: SDK-85 Specifications* :

Central Processor

CPU : 8085A.

Instruction Cycle : 1.3 microsecond.

T_{cy} : 330 ns.

Memory

ROM : 4K bytes using 2 8755s.

RAM : 512 bytes with 2 8155s.

Addressing : Expandable to 64K bytes by use of additional buffers and decoders.

Input/Output

Parallel : 38 lines (expanable to 76).

Serial : Through SID/SOD ports of 8085. Software generated baud rate.

Baud rate : 110

Interfaces

Bus : All signals TTL compatible.

Parallel I/O : All signals TTL compatible.

Serial : 20 mA current loop.

Interrupts

Three levels : (RST 7.5) - Time base input.
(RST 6.5) - TTL input.
INTR - TL input.

---

* SDK Users Manual, order number 9800451B, Intel Corporation, 3065 Bowers Ave., Santa Clara, CA. 95051.

DMA

Hold request : Jumper selectable. TTL compatible input.

Physical Characteristics

Width : 12.0 in.

Height : 10.0 in.

Depth : 0.50 in.

Weight : Approx. 12 oz.

Electrical Characteristics (DC Power Required)

V_{cc} : +5V +/- 5% @ 1.3 amp.

Environmental

Operating temperature : 0-55 °C

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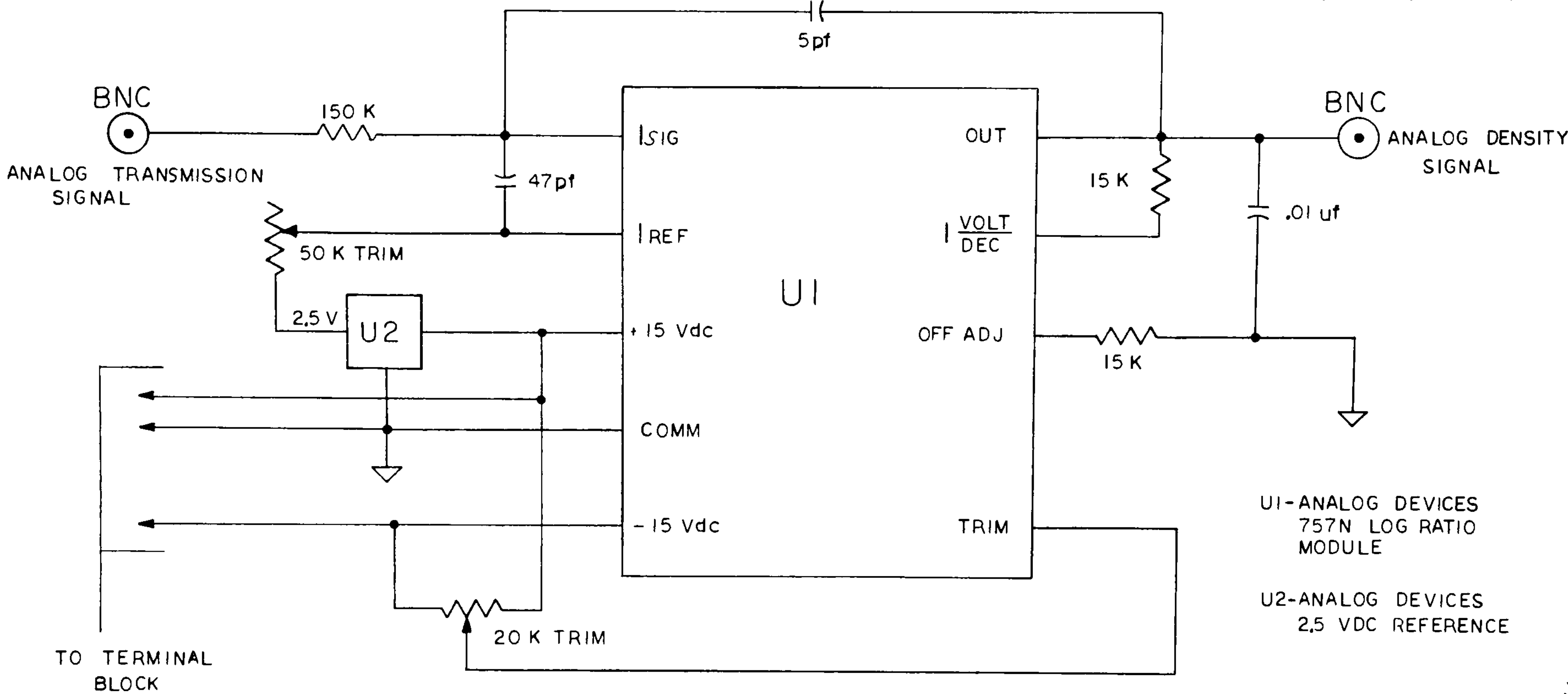
REVISIONS				
ZONE	REV	ECO NO	DATE	APPD



U1-ANALOG DEVICES 757N LOG RATIO MODULE

U2-ANALOG DEVICES 2.5 VDC REFERENCE

	Data
	Acquisition
NEXT ASSY	USED ON

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON XX DEC ± .02 XXX DEC ± .005 ANGLES ± 1°

COMMERCIAL TOLERANCES GOVERN MATERIAL STOCK SIZE FOR MFG TOLERANCES, INCLUDING ROUND PUNCHED AND DRILLED HOLES. SEE SPI E5

DRAWN Steve Cox

APPROVED SC 11/13/81

MATERIAL

FINISH

CHECKER

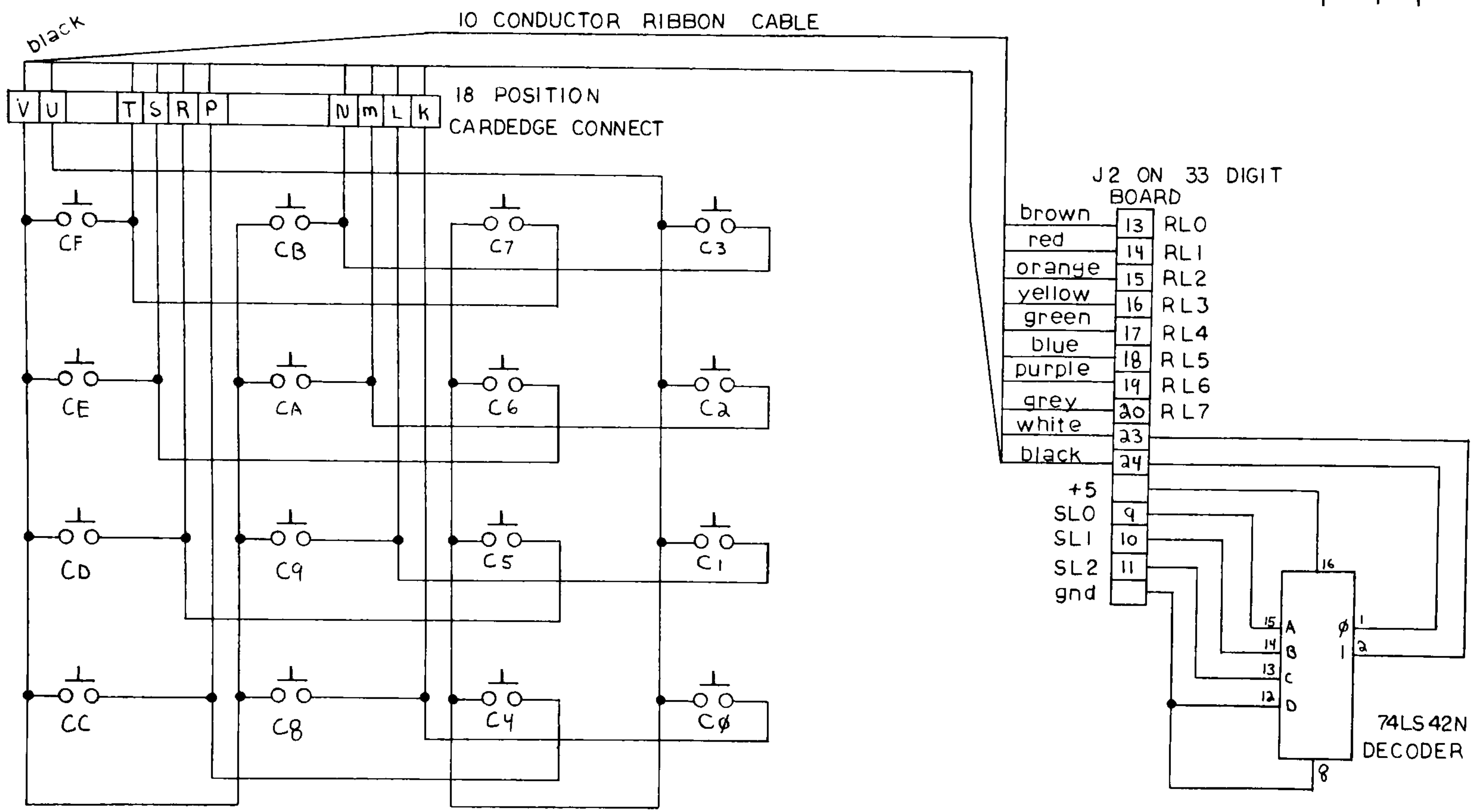
GROUP CODE

LOG AMPLIFER

SIZE B | DRAWING NO

SCALE None | SHEET OF

REVISIONS				
ZONE	REV	ECO NO	DATE	APPD



198

Control Panel	
NEXT ASSY	USED ON

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON XX DEC ± .02 XXX DEC ± .005 ANGLES ± 1°

COMMERCIAL TOLERANCES GOVERN MATERIAL STOCK SIZE FOR MFG TOLERANCES, INCLUDING ROUND PUNCHED AND DRILLED HOLES, SEE SPI-E5

DRAWN S. Cox

APPROVED 12/18/80

MATERIAL

FINISH

CHECKER

GROUP CODE

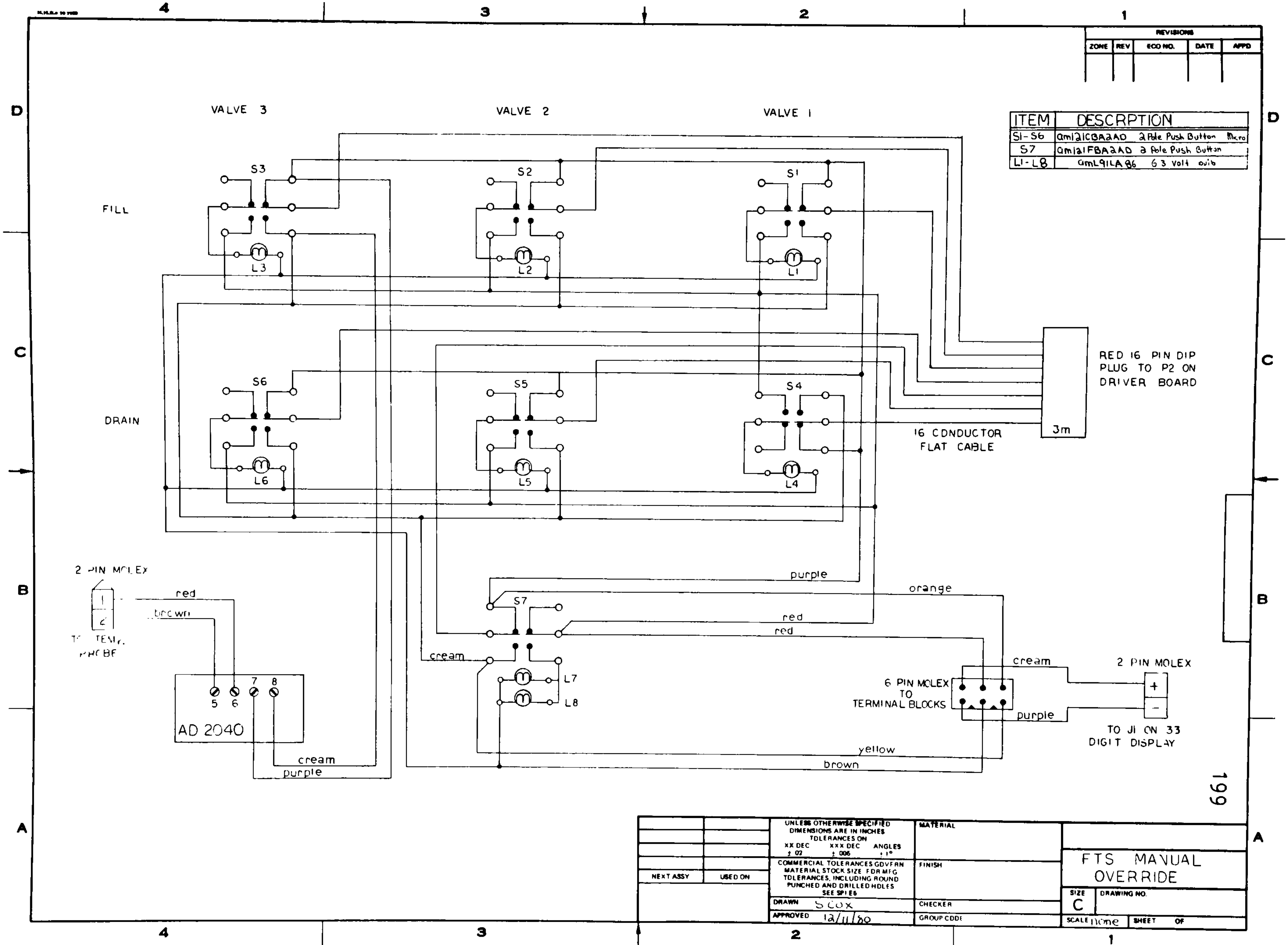
KEY BOARD

SIZE B

DRAWING NO

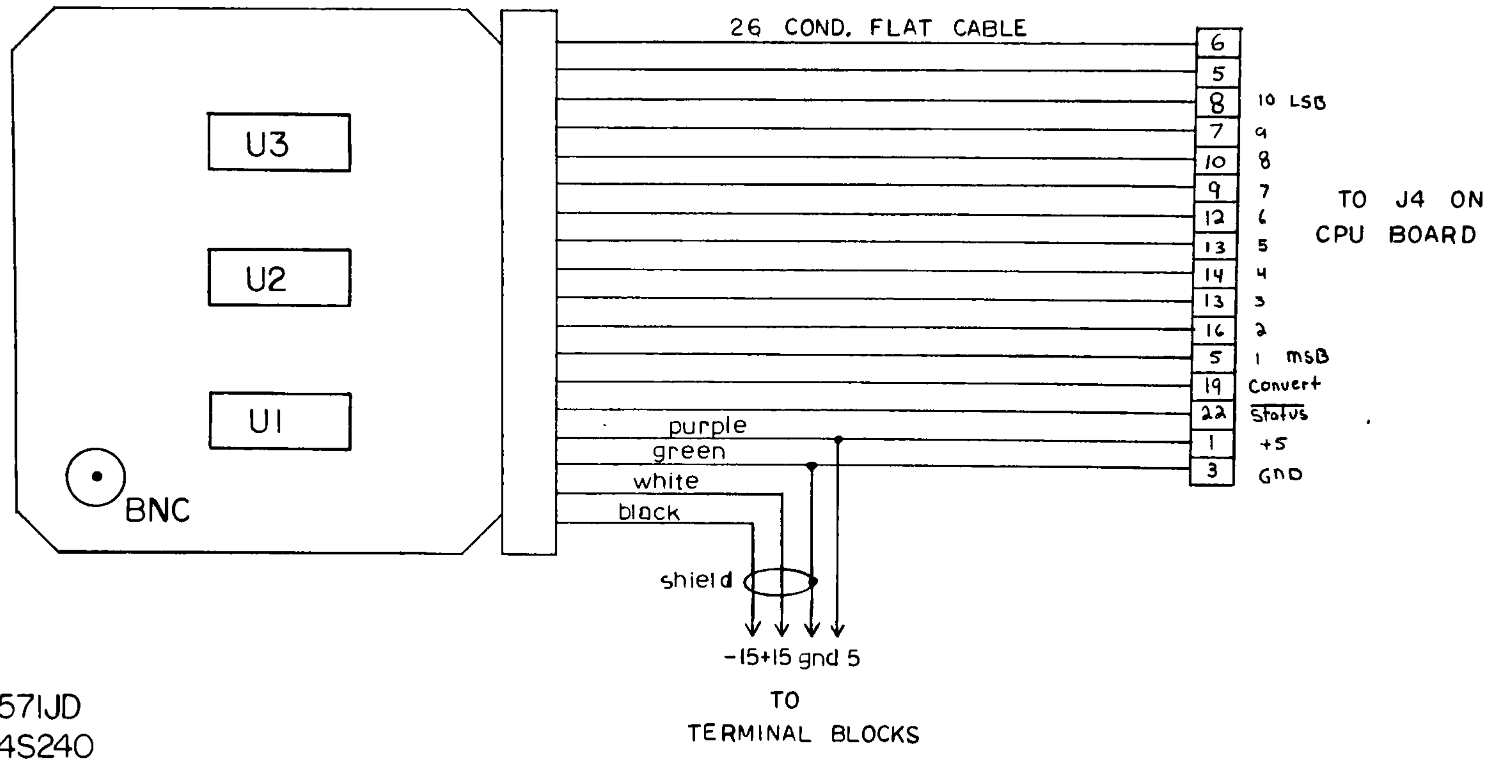
SCALE NONE

SHEET OF



REVISIONS
ZONE
REV
ECO NO.
DATE
APPD
VALVE 3
VALVE 2
VALVE 1
ITEM
DESCRPTION
S1-S6 am12ICBA2AD 2 Pole Push Button Micro
S7 am12IFBA2AD 2 Pole Push Button
L1-L8 amL91LA86 6.3 Volt bulb
FILL
DRAIN
S1
S2
S3
S4
S5
S6
S7
L1
L2
L3
L4
L5
L6
L7
L8
RED 16 PIN DIP
PLUG TO P2 ON
DRIVER BOARD
3m
16 CONDUCTOR
FLAT CABLE
2 PIN MOLEX
TO TEMP.
PROBE
red
brown
purple
orange
cream
yellow
AD 2040
5
6
7
8
6 PIN MOLEX
TO
TERMINAL BLOCKS
TO J1 ON 33
DIGIT DISPLAY
199
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
XX DEC ±.02
XXX DEC ±.005
ANGLES ±1°
COMMERCIAL TOLERANCES GOVERN
MATERIAL STOCK SIZE FOR MFG
TOLERANCES, INCLUDING ROUND
PUNCHED AND DRILLED HOLES
SEE SP1E6
NEXT ASSY
USED ON
MATERIAL
FINISH
DRAWN S COX
APPROVED 12/11/80
CHECKER
GROUP CODE
FTS MANUAL
OVERRIDE
SIZE C
DRAWING NO.
SCALE none
SHEET
OF

REVISIONS				
ZONE	REV	ECO NO.	DATE	APPD
B4	1	—	9/15/81	S. Cox
C3	2	—	2/26/82	✓



U1-AD571JD
U2,3-74S240

200

NEXT ASSY.	USED ON

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON XX DEC ±.02 XXX DEC ±.005 ANGLES ±1°

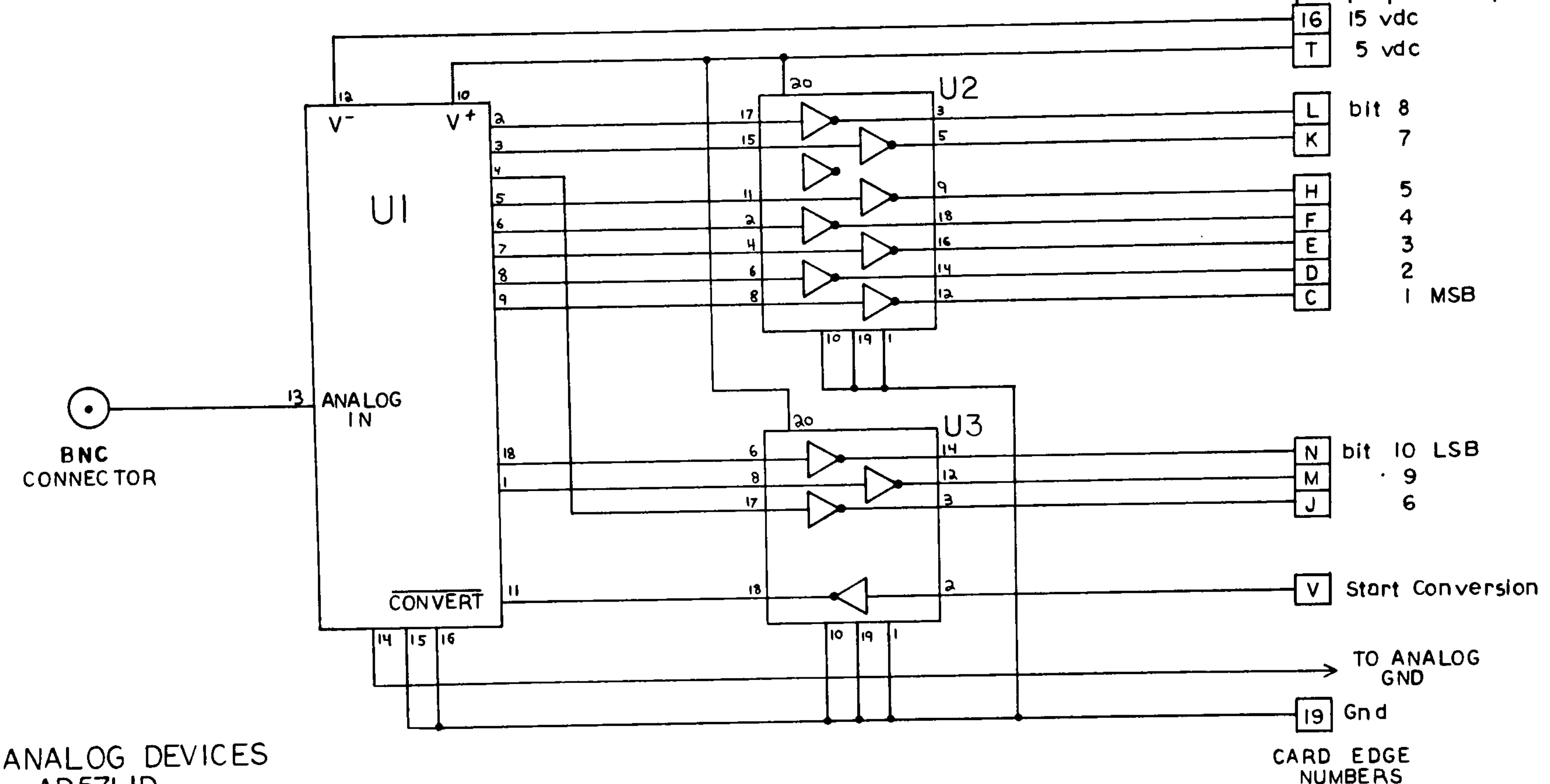
COMMERCIAL TOLERANCES GOVERN MATERIAL STOCK SIZE FOR MFG. TOLERANCES, INCLUDING ROUND PUNCHED AND DRILLED HOLES, SEE SPI-E5

DRAWN	S. Cox
APPROVED	12/10/80
MATERIAL	
FINISH	
CHECKER	
GROUP CODE	

A/D CONVERTER BOARD ASSEMBLY

SIZE	DRAWING NO.		
B			
SCALE	Approx	SHEET	1 OF 1

REVISIONS				
ZONE	REV	ECO NO	DATE	APPD
B3	1	—	2/26/82	S Cox



201

U1-ANALOG DEVICES
AD571JD

U2,U3 SN74S240
LINE DRIVERS

NEXT ASSY	USED ON

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON
XX DEC ± .02 XXX DEC ± .005 ANGLES ± 1°

COMMERCIAL TOLERANCES GOVERN MATERIAL STOCK SIZE FOR MFG. TOLERANCES, INCLUDING ROUND PUNCHED AND DRILLED HOLES, SEE SPI-E5

DRAWN Steve Cox
APPROVED 9/14/81

MATERIAL
FINISH
CHECKER
GROUP CODE

A/D BOARD

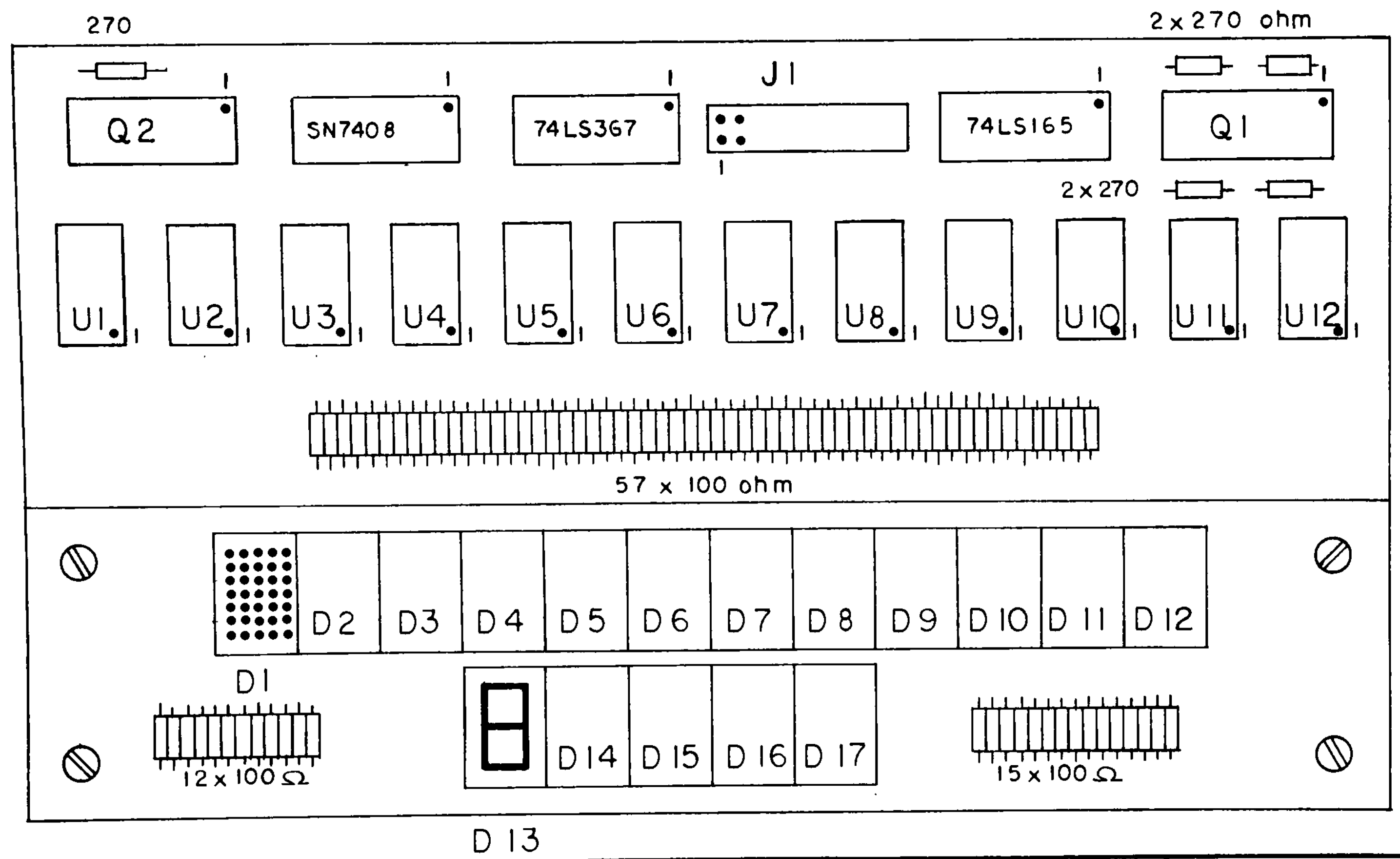
SIZE B
DRAWING NO
SCALE None
SHEET 1 OF 1

202

REVISIONS				
ZONE	REV	ECO NO.	DATE	APPD

Part	Description	
D13-D17	5080-7740	H.P.
D1-D12	TIL-305	T.I.
U_1-U_{12}	74LS164N	
Q_1-Q_2	DH3467CN	
J1	26-Pin Header	

All resistors are 1/4 watt



TOP VIEW

	Control Panel
NEXT ASSY.	USED ON

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ON

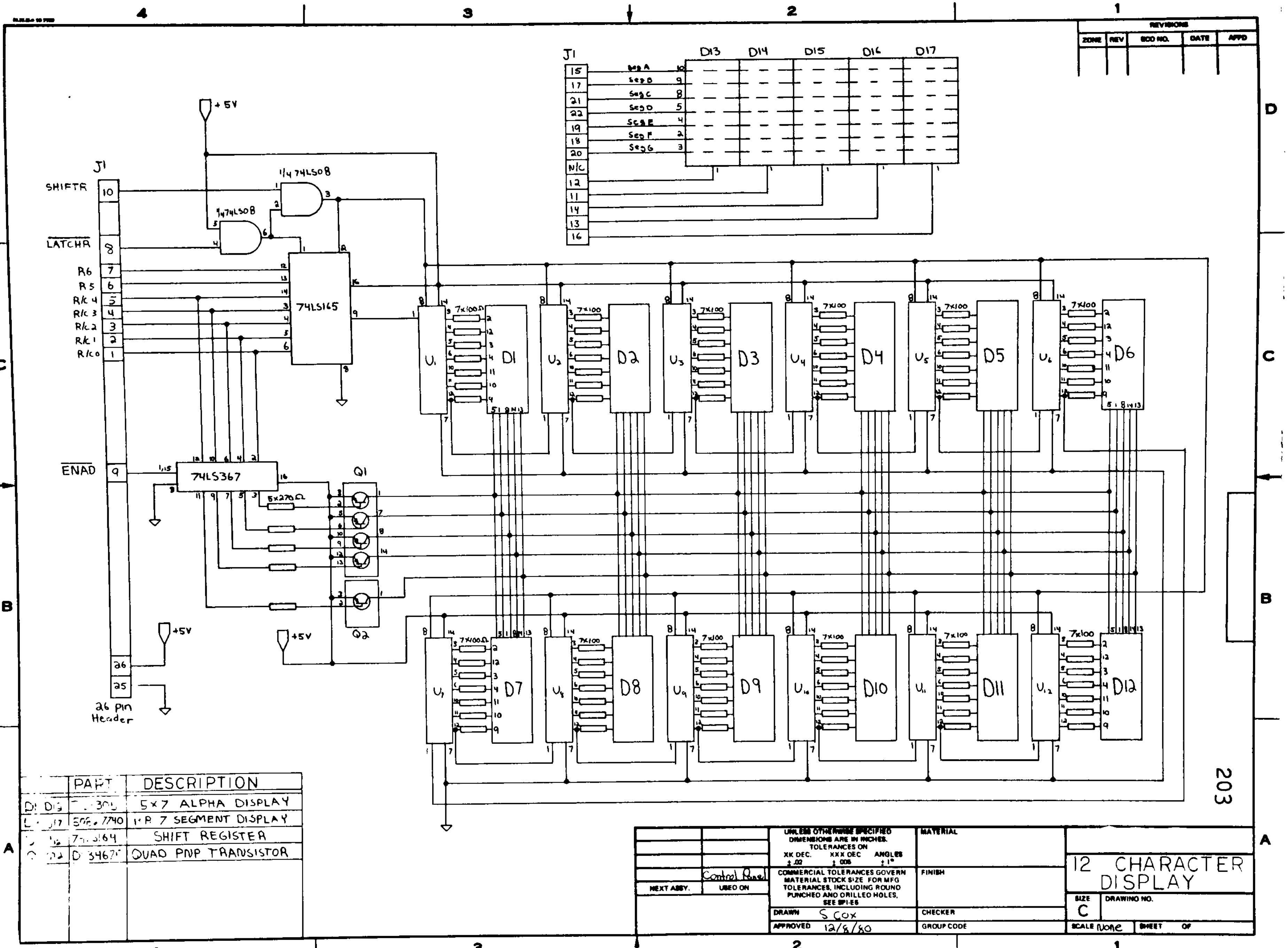
XX DEC	XXX DEC	ANGLES
±.02	±.005	±1°

COMMERCIAL TOLERANCES GOVERN MATERIAL STOCK SIZE FOR MFG TOLERANCES, INCLUDING ROUND PUNCHED AND DRILLED HOLES, SEE SPI-E5

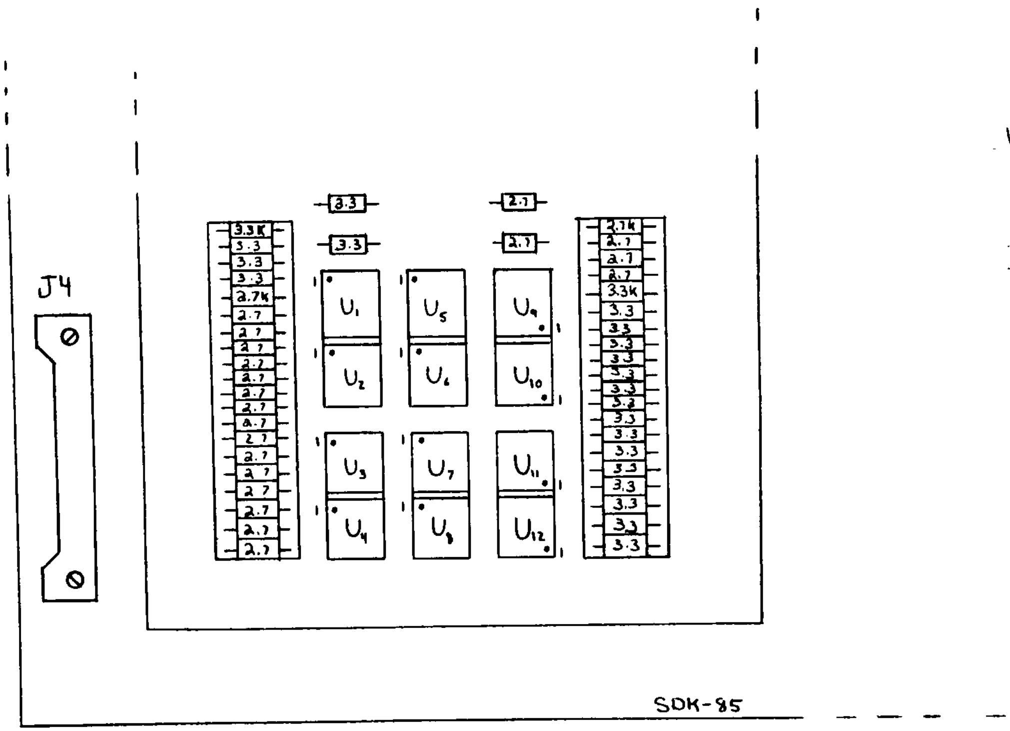
DRAWN	S. Cox
APPROVED	12/9/80
MATERIAL	
FINISH	
CHECKER	
GROUP CODE	

12 CHARACTER DISPLAY ASSEMBLY

SIZE	DRAWING NO.	
B		
SCALE Approx	SHEET	OF



203
12 CHARACTER DISPLAY
J1
SHIFTR
LATCHR
R6
R5
R/C4
R/C3
R/C2
R/C1
R/C0
ENAD
26 pin Header
+5V
1/4 74LS08
74LS165
74LS367
5x270Ω
7x100Ω
Q1
Q2
U1 U2 U3 U4 U5 U6 U7 U8 U9 U10 U11 U12
D1 D2 D3 D4 D5 D6 D7 D8 D9 D10 D11 D12
D13 D14 D15 D16 D17
Seg A
Seg B
Seg C
Seg D
Seg E
Seg F
Seg G
N/C
PART
DESCRIPTION
5x7 ALPHA DISPLAY
H.P. 7 SEGMENT DISPLAY
SHIFT REGISTER
QUAD PNP TRANSISTOR
REVISIONS
ZONE REV ECO NO. DATE APPD
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ON XX DEC. ±.02 XXX DEC ±.005 ANGLES ±1°
COMMERCIAL TOLERANCES GOVERN MATERIAL STOCK SIZE FOR MFG TOLERANCES, INCLUDING ROUND PUNCHED AND DRILLED HOLES, SEE SPI-E6
MATERIAL
FINISH
NEXT ASSY.
USED ON
Control Panel
DRAWN S COX
APPROVED 12/8/80
CHECKER
GROUP CODE
SIZE C
DRAWING NO.
SCALE None
SHEET OF



U_1 to U_{12} are Hewlett Packard HCPL-2730 dual Channel Optocouplers, mounted 2 per 16 pin DIP Socket

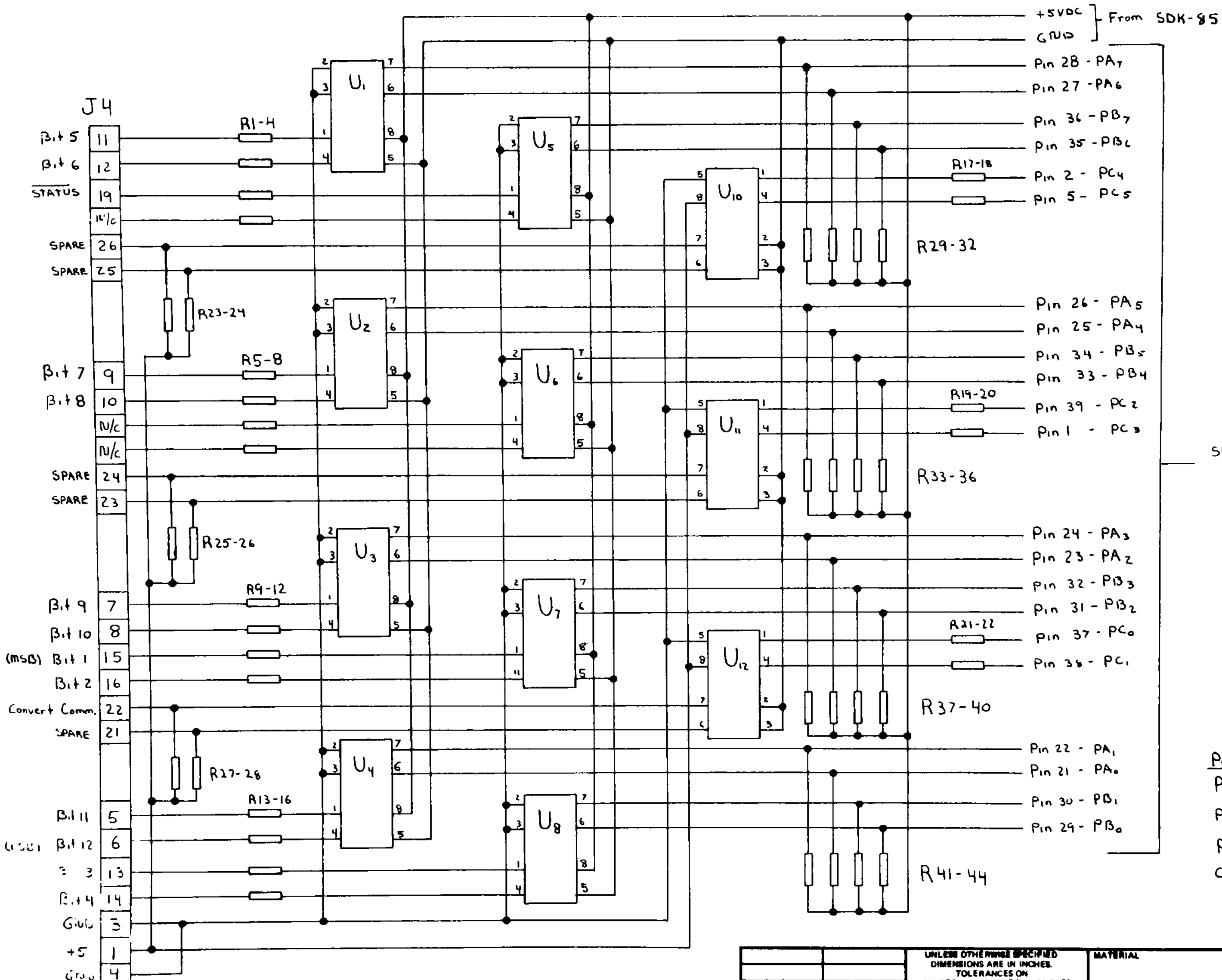
204

REVISIONS				
ZONE	REV	ECO NO.	DATE	APPD

NEXT ASSY.	USED ON: Custom w/w Area	UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ON XX DEC. ±.02 XXX DEC ±.005 ANGLES ±1°	MATERIAL	OPTO ISOLATED I/O ASSEMBLY
		COMMERCIAL TOLERANCES GOVERN MATERIAL STOCK SIZE. FOR MFG. TOLERANCES, INCLUDING ROUND PUNCHED AND DRILLED HOLES, SEE SPI-E5	FINISH	SIZE B / DRAWING NO.
		DRAWN S. Cox	CHECKER	
		APPROVED 12/6/80	GROUP CODE	SCALE Approx / SHEET OF

H.N.S. 10 5150

205



Parts:

R1 to R22 - 2.7 kΩ 1/4 w
R23 to R44 - 3.3 kΩ 1/4 w
U1 to U12 - H/P HCPL-2730
J4 - 26 pin header

Port:	Address:	Status:
PA_{0-7}	29H	Input
PB_{0-7}	2AH	Input
PC_{0-5}	2BH	Output
C/S	28H	D.N.A.

REVISIONS				
ZONE	REV	ECO NO.	DATE	APPD

NEXT ASSY. | USED ON: SDK-85 A/D Conver

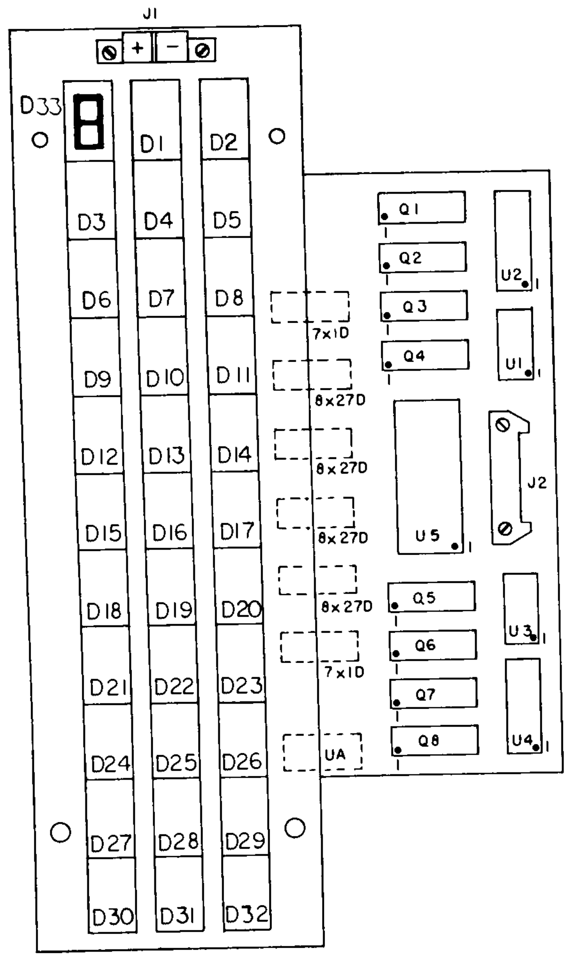
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ON XX DEC. ±.02 XXX DEC ±.005 ANGLES ±1°

COMMERCIAL TOLERANCES GOVERN MATERIAL STOCK SIZE FOR MFG TOLERANCES, INCLUDING ROUND PUNCHED AND DRILLED HOLES. SEE SPI E6

DRAWN: S Cox
APPROVED: 12/6/80
MATERIAL
FINISH
CHECKER
GROUP CODE

OPTO-ISOLATED I/O

SIZE: C | DRAWING NO | SCALE: None | SHEET | OF



ITEM	TYPE	DESCRIPTION	QTY
Q1-Q8	DH3467CN	QUAD PNP Transistor	8
U_1 and U_3	SN7448	BCD to 7 Segment Decoder	2
U_2 and U_4	SN75498	Hex Inverting Drivers	2
U_5	SN74154	1 of 16 Decoder	1
D1-D33	5082-7730	HP Seven Segment Display	33
UA	SN7442	BCD to Decimal Decoder	1
J1		2 pin molex	1
J2		26 pin Right Angle Header	1

NOTES

1. DATA FROM THE 8279 IS SENT AS 8 BITS MADE UP OF 2 NYBBLES, A & B.
2. U1 DECODES NYBBLE A AND IN TURN DRIVES U2 AND Q1-Q4. DIGITS D1-D16 ARE THEREFORE WRITTEN TO THRU NYBBLE A.
3. SIMILARLY, D17-D32 ARE WRITTEN TO THRU NYBBLE B.
4. D33 IS HARD-WIRED TO DISPLAY ZERO.
5. RESISTORS ARE IN OHMS AND RATED 1/4 WATT.

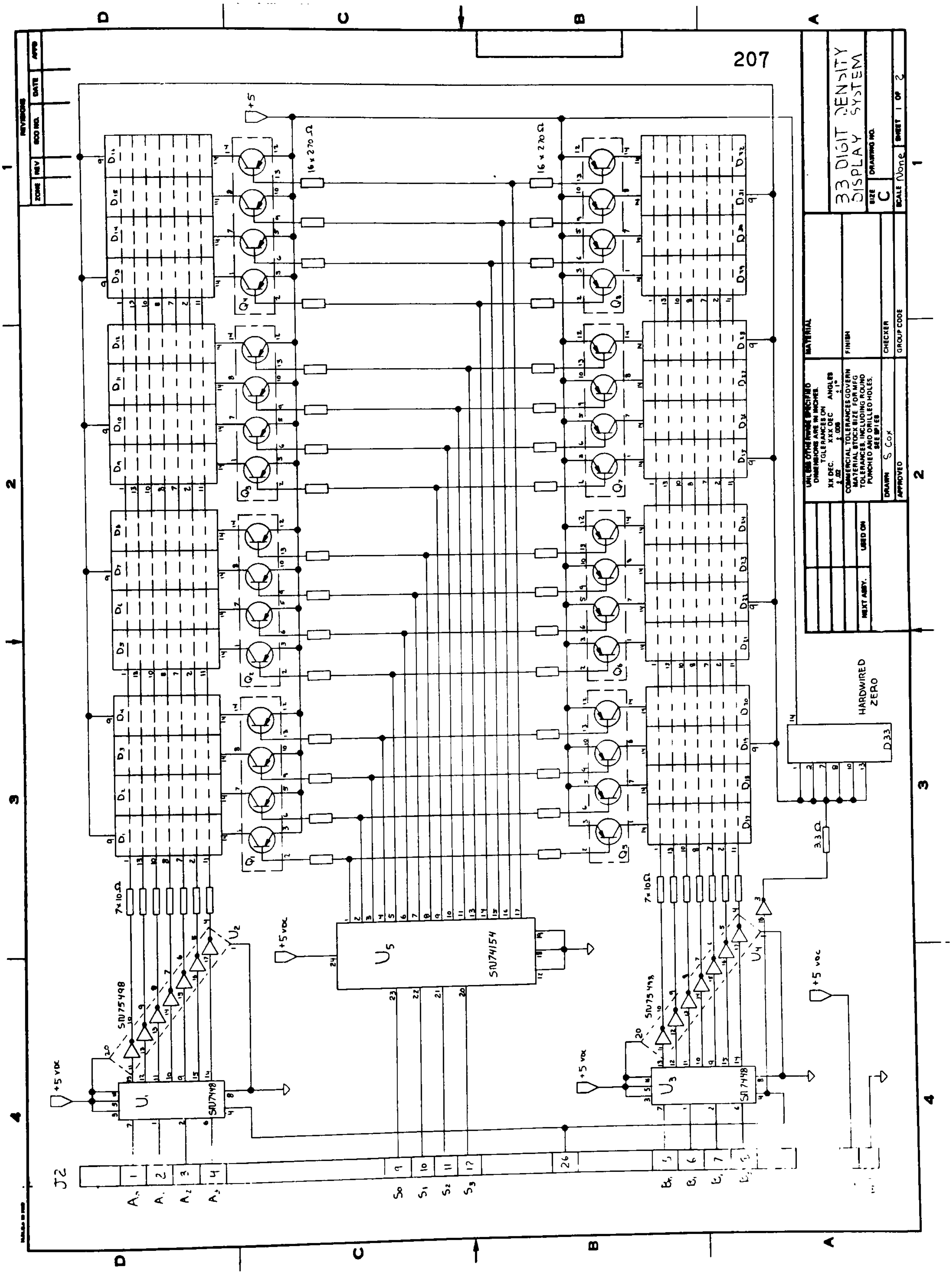
206

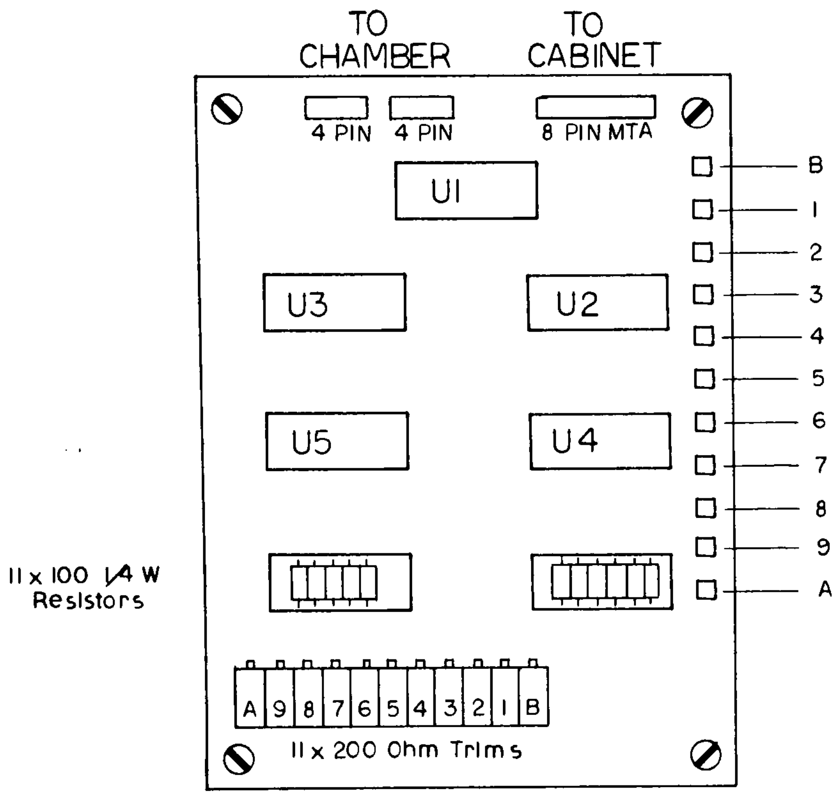
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ON XX DEC ±.02 XXX DEC ±.005 ANGLES ±1°	MATERIAL
COMMERCIAL TOLERANCES GOVERN MATERIAL STOCK SIZE FOR MFG TOLERANCES, INCLUDING ROUND PUNCHED AND DRILLED HOLES. SEE SPI-ES	FINISH
DRAWN S. Cox	CHECKER
APPROVED 12/9/80	GROUP CODE

NEXT ASSY | USED ON

33 DIGIT DISPLAY ASSEMBLY

SIZE C | DRAWING NO. | SCALE | SHEET OF


33 DIGIT DENSITY DISPLAY SYSTEM
SIZE C
SCALE None
SHEET 1 OF 2
DRAWN S Cox
HARDWIRED ZERO
D33
16 x 270 Ω
7 x 10 Ω
3.3 Ω
SN74154
SN75498
SN7448
+5 VDC
J2



TO 11 IREDS IN CHAMBER TOP

U1 - 74LS154
U2,3 - 7414
U4,5 - 9664

TOP VIEW

208

REVISIONS				
ZONE	REV	ECO NO.	DATE	APPD

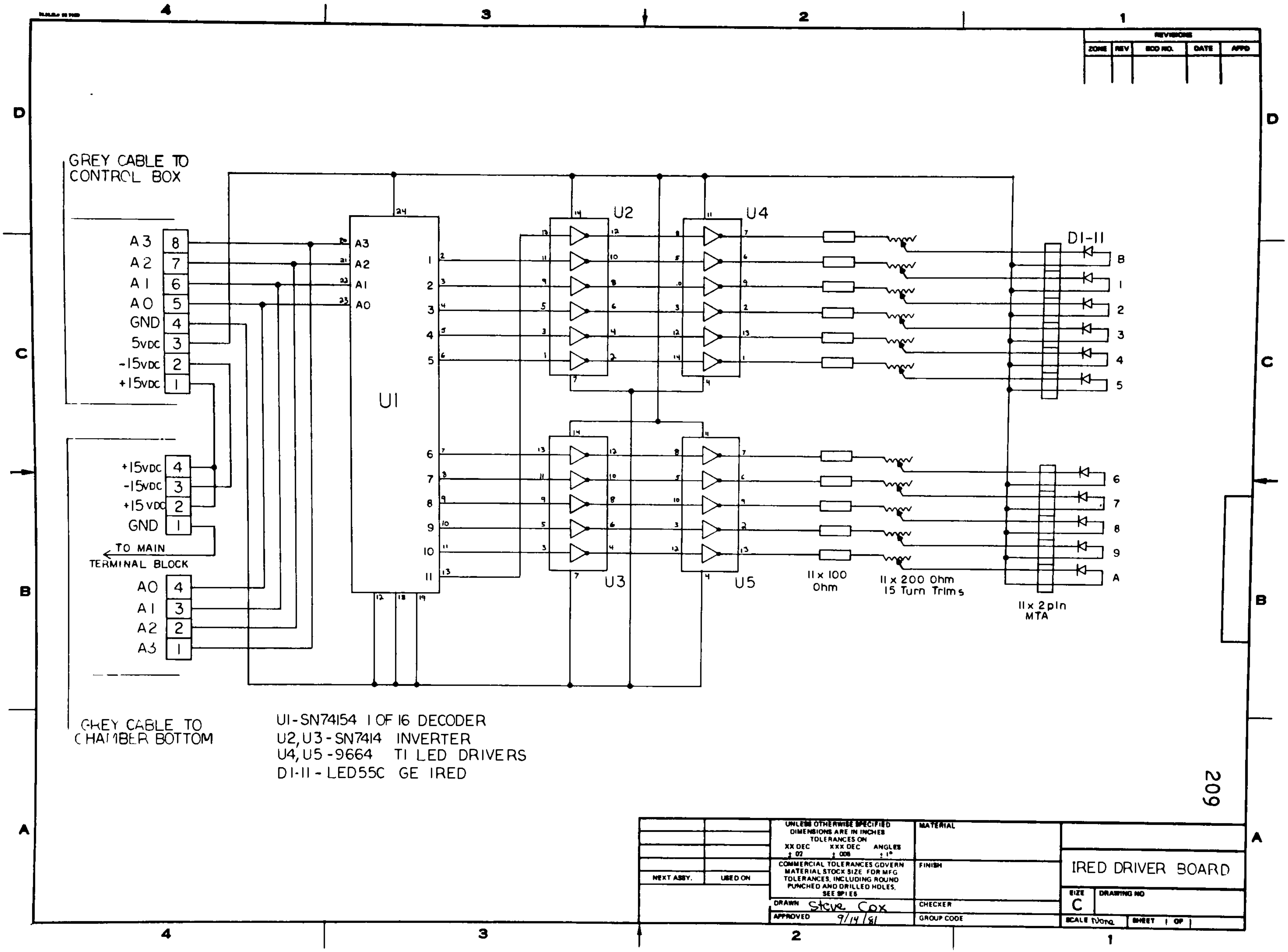
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON XX DEC ±.02 XXX DEC ±.005 ANGLES ±1°

COMMERCIAL TOLERANCES GOVERN MATERIAL STOCK SIZE FOR MFG. TOLERANCES, INCLUDING ROUND PUNCHED AND DRILLED HOLES, SEE SPI-E5

NEXT ASSY	USED ON
DRAWN	Steve Cox
APPROVED	9/15/81
MATERIAL	
FINISH	
CHECKER	
GROUP CODE	

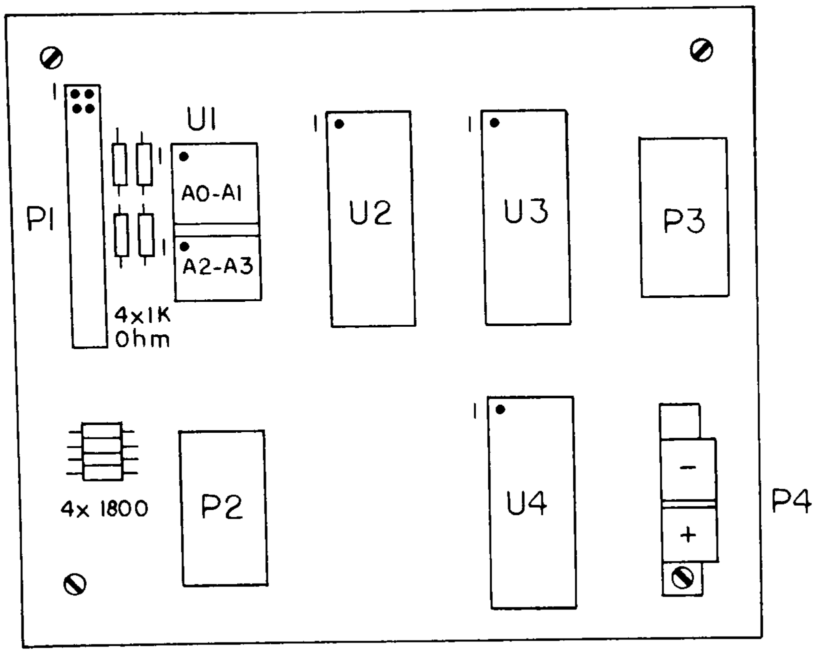
IRED DRIVER BOARD ASSEMBLY

SIZE B	DRAWING NO	SCALE 2:1	SHEET 1 OF 1


GREY CABLE TO CONTROL BOX
A3 8
A2 7
A1 6
A0 5
GND 4
5VDC 3
-15VDC 2
+15VDC 1
+15VDC 4
-15VDC 3
+15VDC 2
GND 1
TO MAIN TERMINAL BLOCK
A0 4
A1 3
A2 2
A3 1
GREY CABLE TO CHAMBER BOTTOM
U1
U2
U3
U4
U5
D1-11
11 x 100 Ohm
11 x 200 Ohm 15 Turn Trims
11 x 2 pin MTA
U1-SN74154 1 OF 16 DECODER
U2, U3-SN7414 INVERTER
U4, U5-9664 TI LED DRIVERS
D1-11-LED55C GE IRED
REVISIONS
ZONE
REV
ECO NO.
DATE
APPD
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON XX DEC ±.02 XXX DEC ±.005 ANGLES ±1°
COMMERCIAL TOLERANCES GOVERN MATERIAL STOCK SIZE FOR MFG TOLERANCES, INCLUDING ROUND PUNCHED AND DRILLED HOLES, SEE SPIES
MATERIAL
FINISH
NEXT ASSY.
USED ON
DRAWN Steve Cox
APPROVED 9/14/81
CHECKER
GROUP CODE
IRED DRIVER BOARD
SIZE C
DRAWING NO
SCALE None
SHEET 1 OF

REVISIONS				
ZONE	REV	ECO NO.	DATE	APPD

ITEM	TYPE	DESCRIPTION	QTY
U_1	HCPL-2730	HP OPTO-Isolator	2
U_2-U_4	74LS240	Bus Driver, inverting	3
P1		26 pin Header	1
P2-P3		16 Pin DIP Socket	2
P4		2 Pin molex	1
Resistors are Rated 1/4 watt			



TOP VIEW

	F.T.S. Relay
	Control
NEXT ASSY.	USED ON

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES.
TOLERANCES ON
XX DEC ± .02 XXX DEC ± .005 ANGLES ± 1°

COMMERCIAL TOLERANCES GOVERN MATERIAL STOCK SIZE. FOR MFG. TOLERANCES, INCLUDING ROUND PUNCHED AND DRILLED HOLES, SEE SPI-E6

DRAWN S. Cox

APPROVED 12/10/80

MATERIAL

FINISH

CHECKER

GROUP CODE

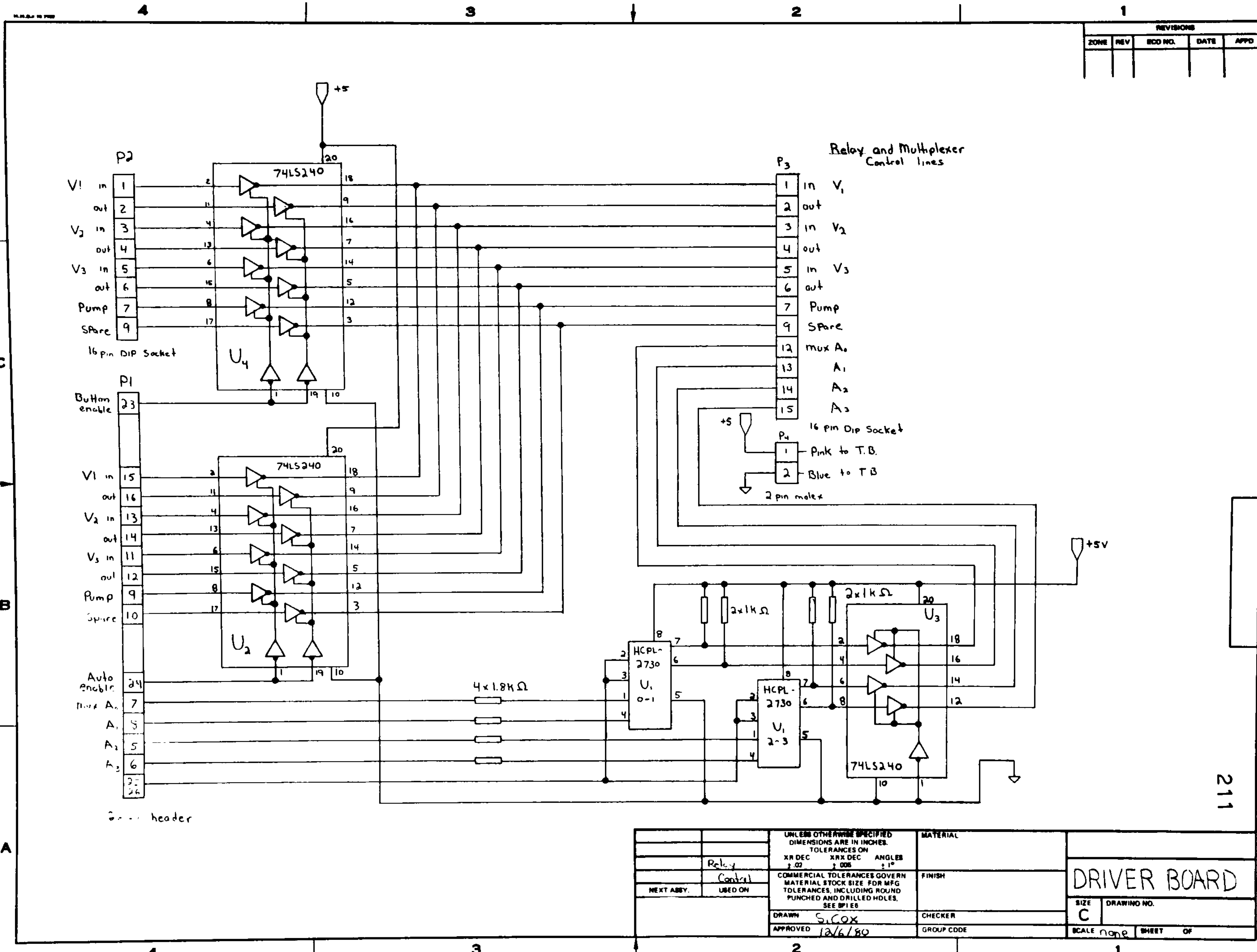
DRIVER BOARD ASSEMBLY

SIZE B

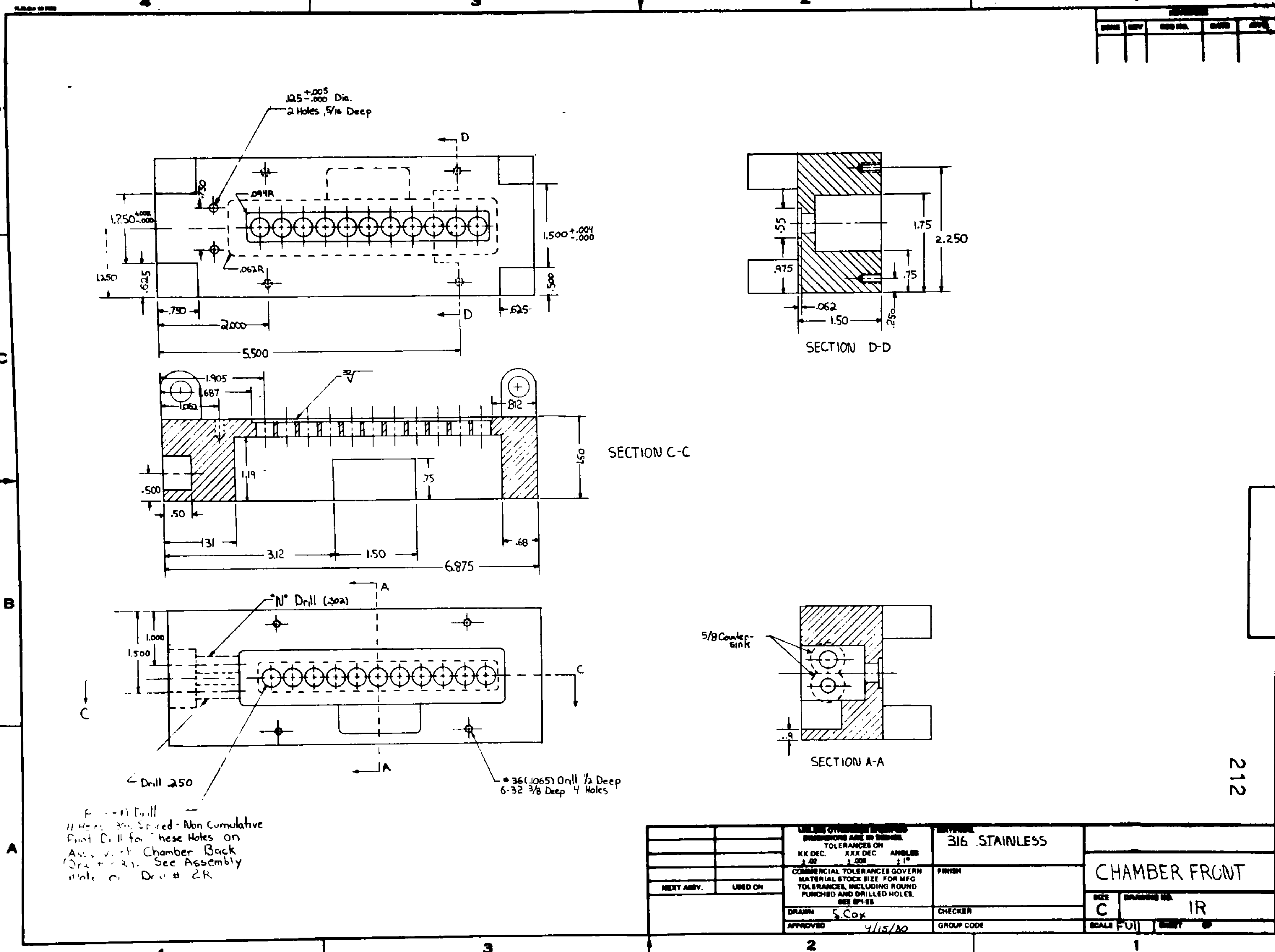
DRAWING NO.

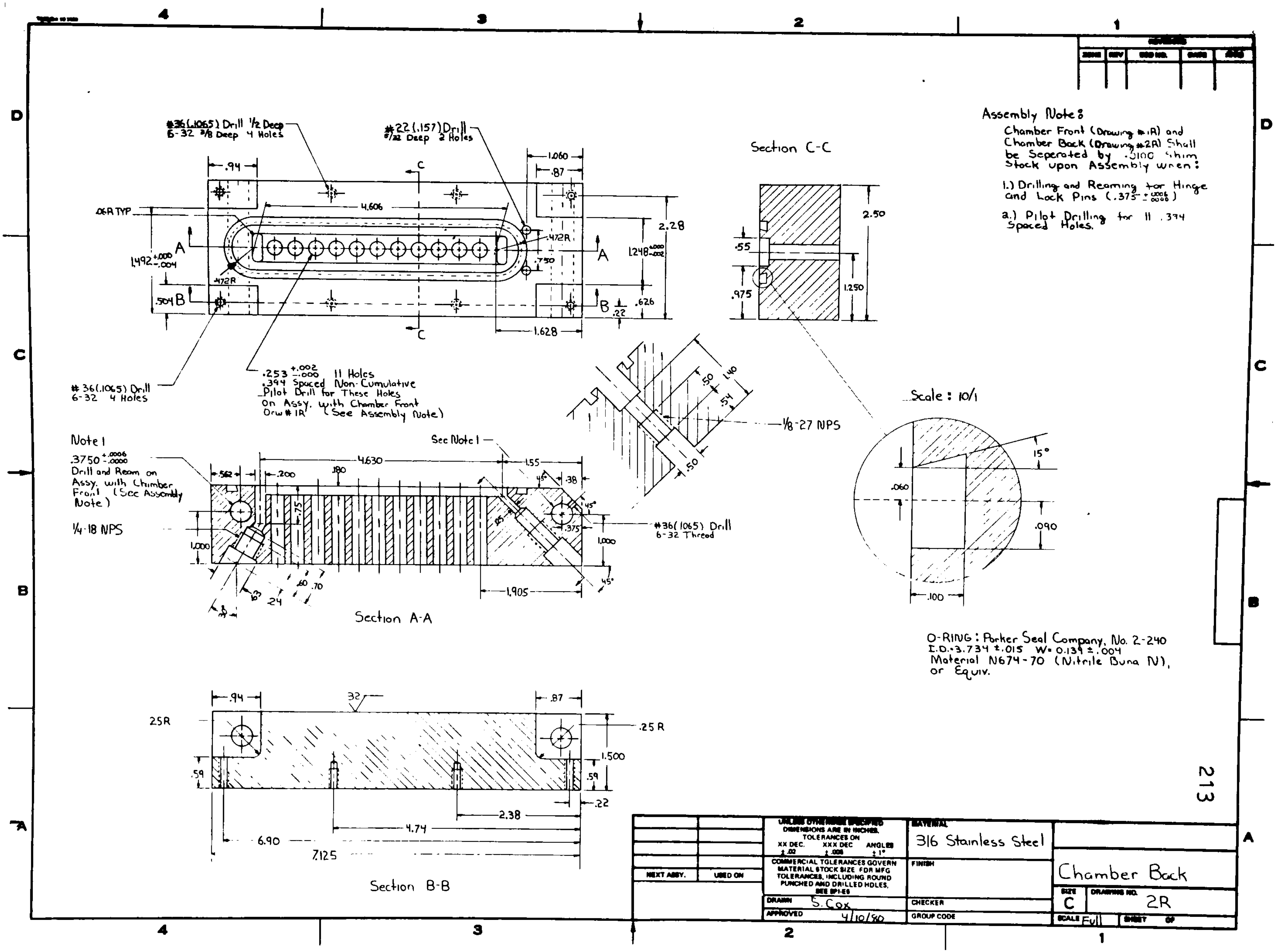
SCALE Approx

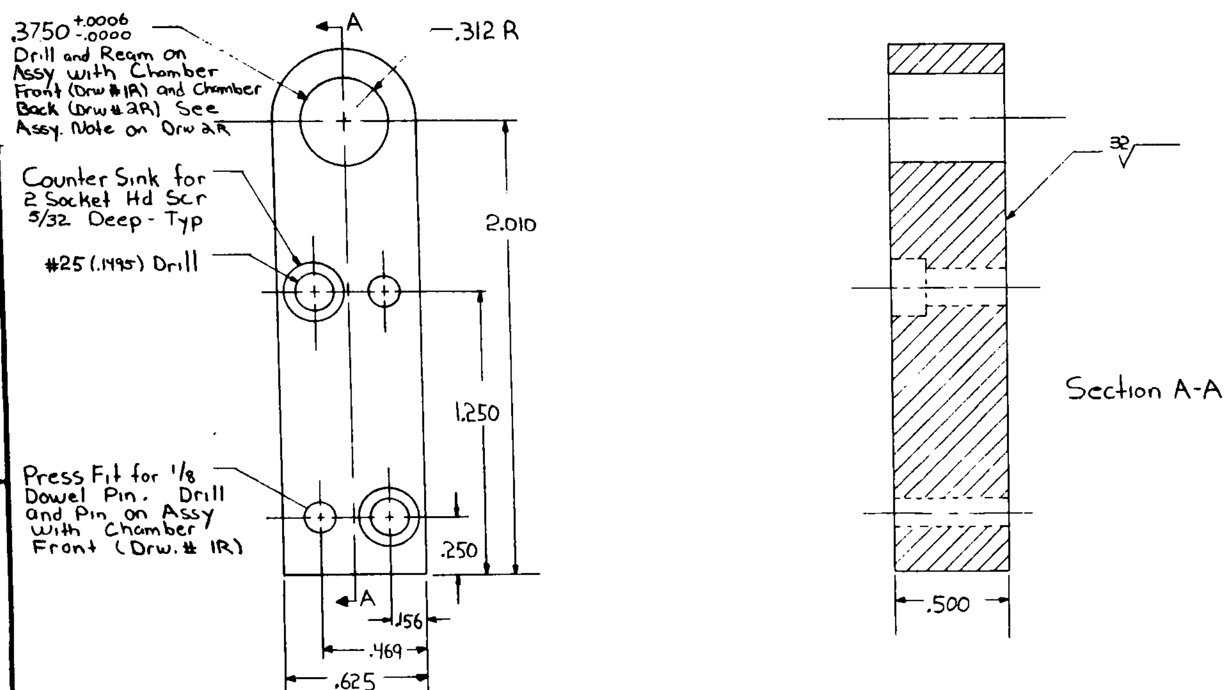
SHEET OF



P2
V1 in
out
V2 in
out
V3 in
out
Pump
Spare
16 pin DIP Socket
P1
Button enable
V1 in
out
V2 in
out
V3 in
out
Pump
Spare
Auto enable
mux A0
A1
A2
A3
header
74LS240
U4
74LS240
U2
Relay and Multiplexer Control lines
P3
in V1
out
in V2
out
in V3
out
Pump
Spare
mux A0
A1
A2
A3
16 pin Dip Socket
P4
Pink to T.B.
Blue to TB
2 pin molex
+5
+5V
2x1kΩ
2x1kΩ
4x1.8KΩ
HCPL-2730
U1 0-1
HCPL-2730
U1 2-3
74LS240
U3
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ON XX DEC ±.02 XXX DEC ±.005 ANGLES ±1°
COMMERCIAL TOLERANCES GOVERN MATERIAL STOCK SIZE FOR MFG TOLERANCES, INCLUDING ROUND PUNCHED AND DRILLED HOLES. SEE SPI E6
MATERIAL
FINISH
Relay Control
NEXT ASSY.
USED ON
DRAWN S. Cox
APPROVED 12/6/80
CHECKER
GROUP CODE
DRIVER BOARD
SIZE C
DRAWING NO.
SCALE none
SHEET OF
REVISIONS
ZONE REV ECO NO. DATE APPD


.125 +.005 -.000 Dia.
2 Holes, 5/16 Deep
1.750 +.002 -.000
1.250
.625
.750
.094R
.062R
1.500 +.004 -.000
.500
.625
2.000
5.500
D
SECTION D-D
.55
.975
1.75
2.250
.75
.062
1.50
.250
1.905
.687
1.062
.812
32
SECTION C-C
1.19
.75
.500
.50
1.31
3.12
1.50
6.875
.68
"N" Drill (.302)
1.000
1.500
C
A
Drill .250
#36 (.1065) Drill 1/2 Deep
6-32 3/8 Deep 4 Holes
5/8 Countersink
.19
SECTION A-A
11 Holes .300 Spaced - Non Cumulative
See Assembly
Chamber Back
316 STAINLESS
TOLERANCES ON
XX DEC. ±.02
XXX DEC ±.005
ANGLES ±1°
COMMERCIAL TOLERANCES GOVERN MATERIAL STOCK SIZE FOR MFG TOLERANCES, INCLUDING ROUND PUNCHED AND DRILLED HOLES.
NEXT ASSY.
USED ON
FINISH
DRAWN S. Cox
APPROVED 4/15/80
CHECKER
GROUP CODE
CHAMBER FRONT
SIZE C
IR
SCALE FULL
SHEET

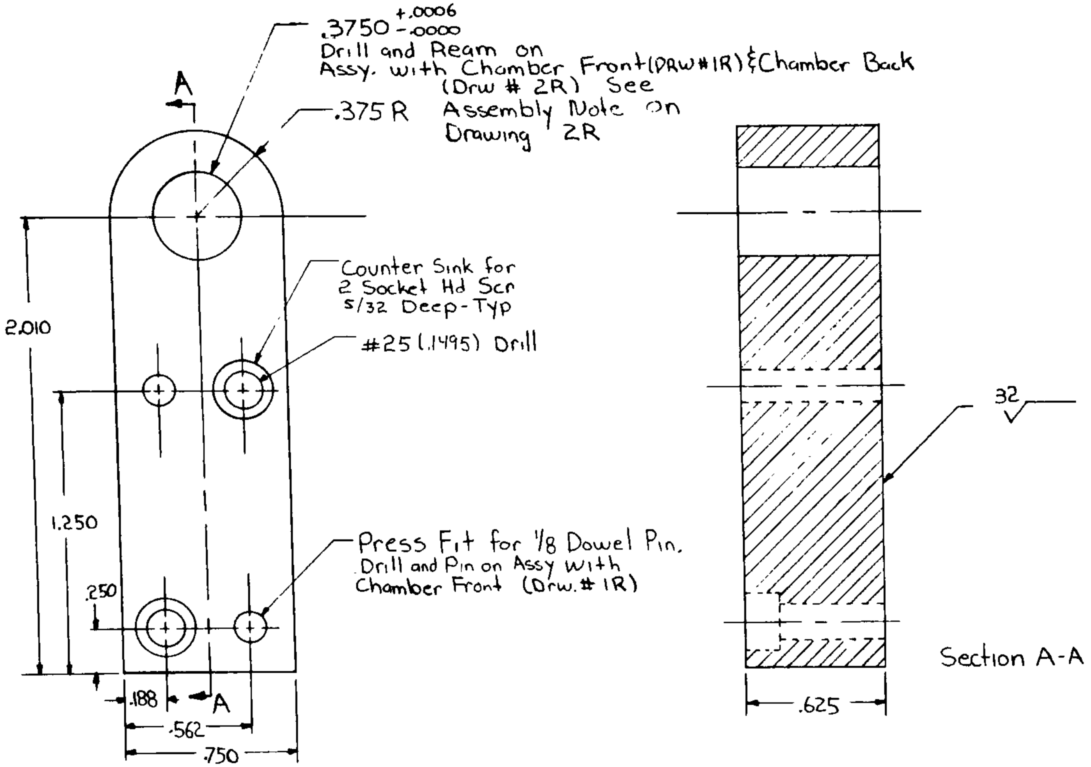

213
Assembly Note:
Chamber Front (Drawing #1R) and Chamber Back (Drawing #2R) Shall be Seperated by .0100 Shim Stock upon Assembly when:
1.) Drilling and Reaming for Hinge and Lock Pins (.375 +.0006 -.0000)
a.) Pilot Drilling for 11 .394 Spaced Holes.
#36(.1065) Drill 1/2 Deep 6-32 3/8 Deep 4 Holes
#22(.157) Drill 5/32 Deep 2 Holes
#36(.1065) Drill 6-32 4 Holes
.253 +.002 -.000 11 Holes .394 Spaced Non-Cumulative Pilot Drill for These Holes On Assy. with Chamber Front Drw #1R (See Assembly Note)
.06R TYP
.472R
Section C-C
Scale: 10/1
1/8-27 NPS
Note 1
.3750 +.0006 -.0000 Drill and Ream on Assy. with Chamber Front (See Assembly Note)
1/4-18 NPS
See Note 1
#36(.1065) Drill 6-32 Thread
Section A-A
Section B-B
O-RING: Parker Seal Company, No. 2-240 I.D.=3.734 ±.015 W=0.139 ±.004 Material N674-70 (Nitrile Buna N), or Equiv.
MATERIAL 316 Stainless Steel
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ON XX DEC. ±.02 XXX DEC ±.005 ANGLES ±1°
COMMERCIAL TOLERANCES GOVERN MATERIAL STOCK SIZE FOR MFG TOLERANCES, INCLUDING ROUND PUNCHED AND DRILLED HOLES, SEE BPI-ES
NEXT ASSY. USED ON
FINISH
DRAWN S. Cox
APPROVED 4/10/80
CHECKER
GROUP CODE
Chamber Back
SIZE C
DRAWING NO. 2R
SCALE Full
SHEET OF



2 Required

REVISIONS				
ZONE	REV	ECO NO.	DATE	APPD

NEXT ASSY.	USED ON		
	Chamber Front (1R)		
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON XX DEC. ± .02 XXX DEC ± .005 ANGLES ± 1°	MATERIAL 316 Stainless Steel		
COMMERCIAL TOLERANCES GOVERN MATERIAL STOCK SIZE. FOR MFG TOLERANCES, INCLUDING ROUND PUNCHED AND DRILLED HOLES, SEE SPI-E5	FINISH		LOCK
DRAWN S. Cox	CHECKER 4/8/80	SIZE B	DRAWING NO. 4R
APPROVED	GROUP CODE	SCALE 2 : 1	SHEET OF



2 Required

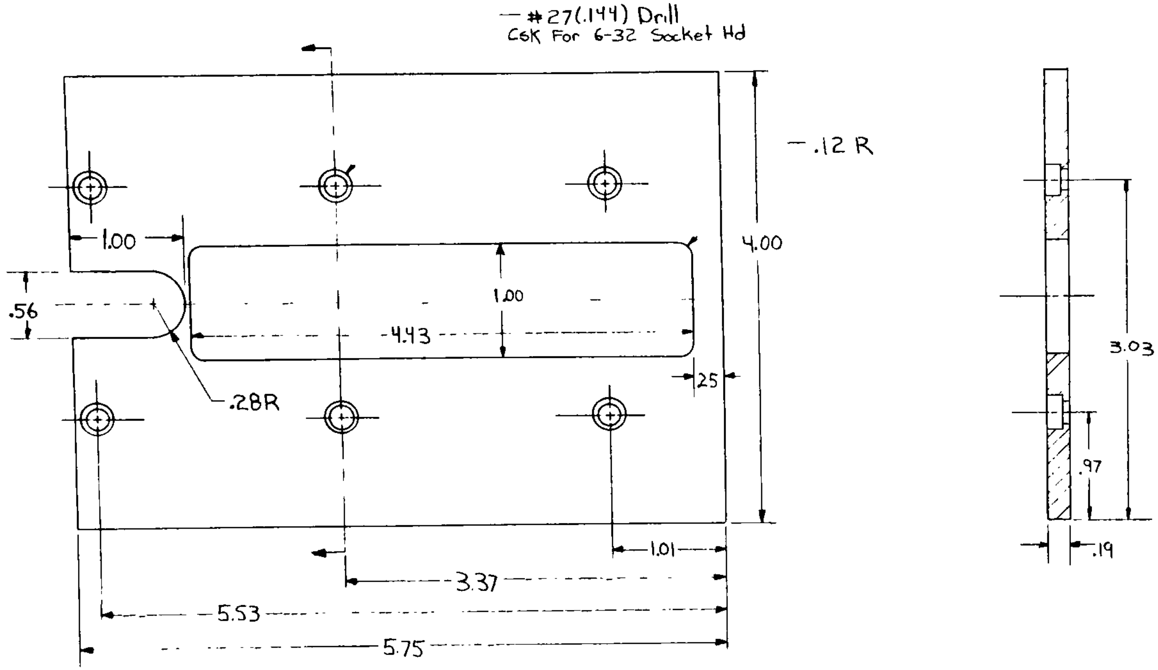
REVISIONS				
ZONE	REV	ECO NO.	DATE	APPD

		UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ON XX DEC. ±.02 XXX DEC. ±.005 ANGLES ±1°	MATERIAL 316 Stainless Steel	
	Chamber Front	COMMERCIAL TOLERANCES GOVERN MATERIAL STOCK SIZE. FOR MFG. TOLERANCES, INCLUDING ROUND PUNCHED AND DRILLED HOLES, SEE SPI-E5	FINISH	HINGE
NEXT ASSY.	USED ON			SIZE B DRAWING NO. 3R
		DRAWN S. Cox	CHECKER	
		APPROVED 4/10/80	GROUP CODE	SCALE 2:1 SHEET OF

216

REVISIONS

ZONE	REV	ECO NO.	DATE	APPD



	Chamber Back
NEXT ASSY.	USED ON

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON

XX DEC	XXX DEC	ANGLES
± .02	± .005	± 1°

COMMERCIAL TOLERANCES GOVERN MATERIAL STOCK SIZE FOR MFG. TOLERANCES, INCLUDING ROUND PUNCHED AND DRILLED HOLES, SEE SPI-E5

DRAWN S. Cox

APPROVED 4/17/80

MATERIAL 316 Stainless Steel

FINISH

CHECKER

GROUP CODE

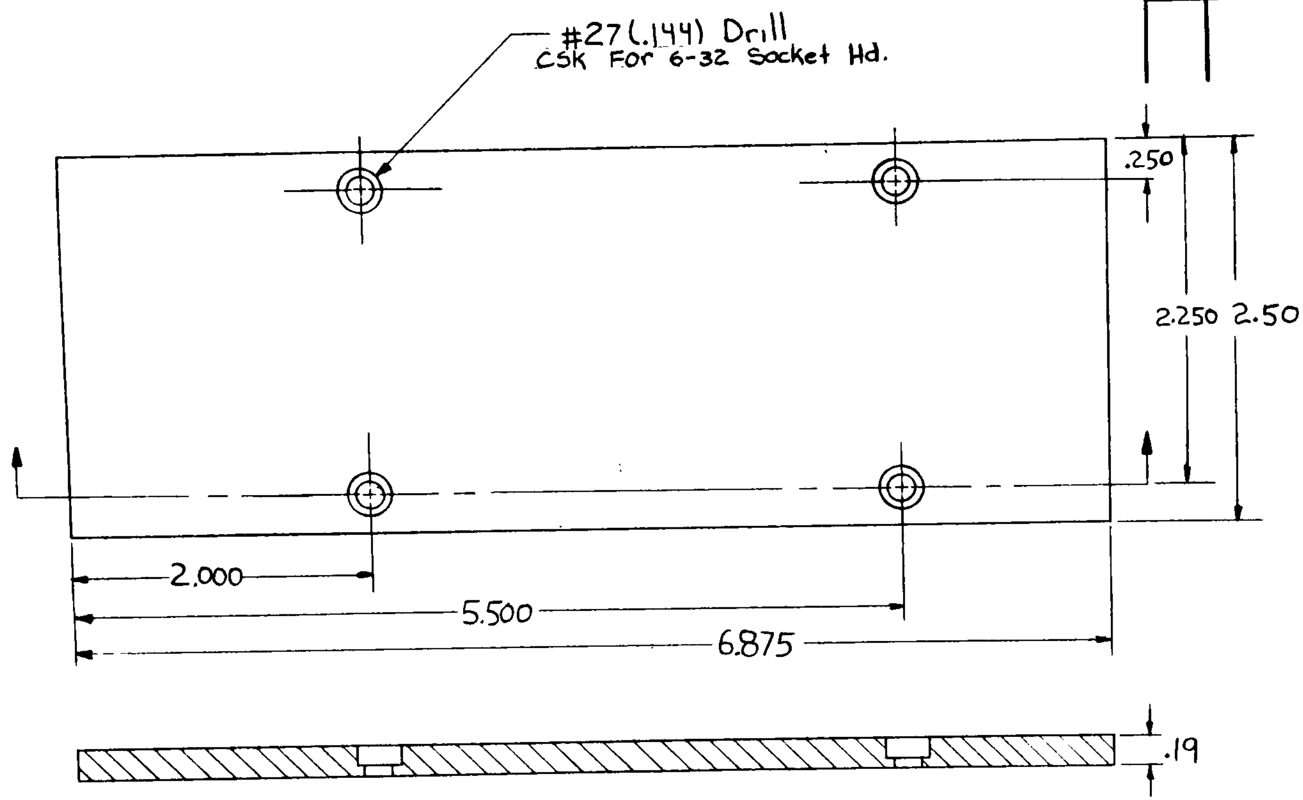
Chamber Mount

SIZE B

DRAWING NO 9R

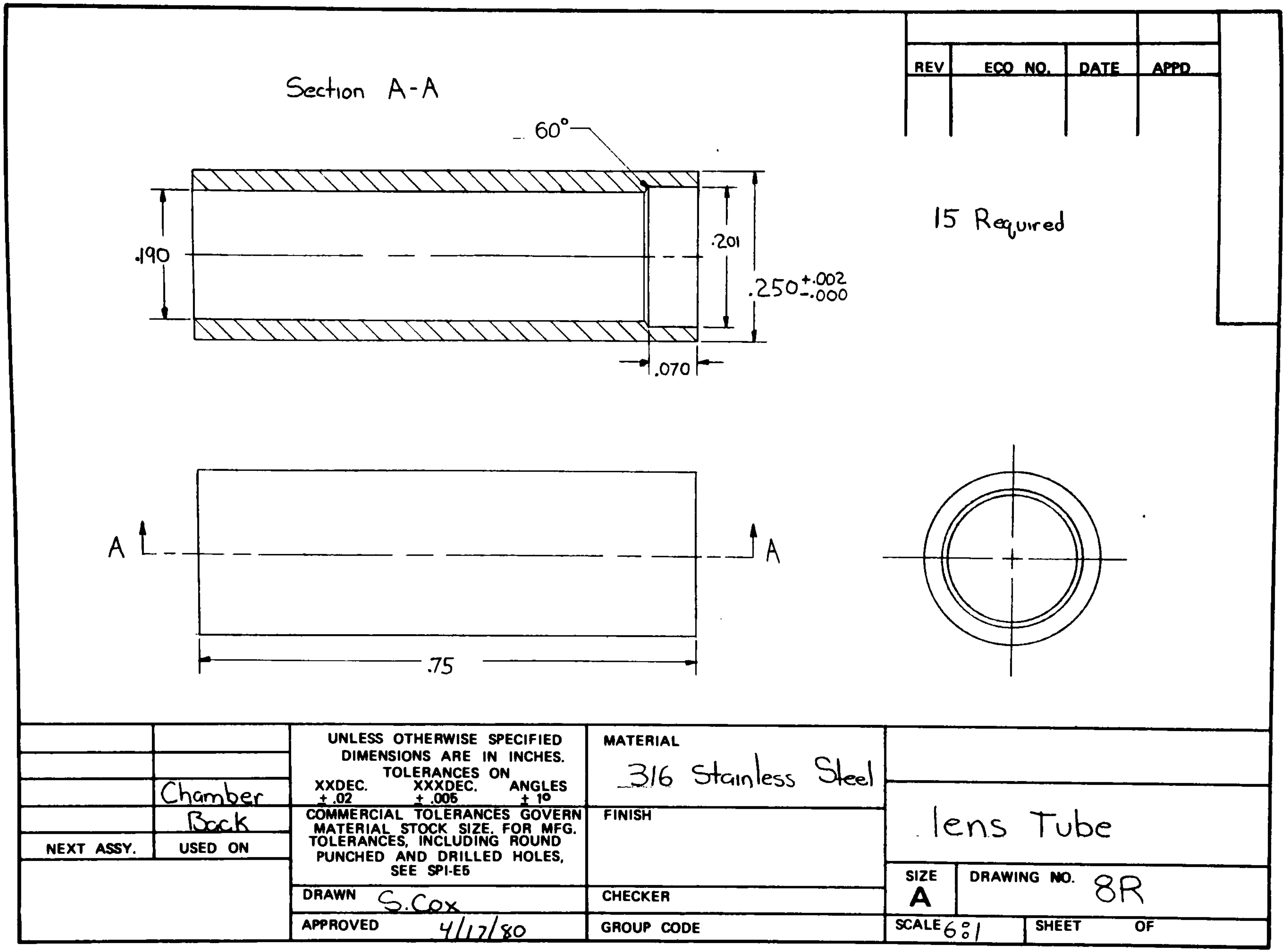
SCALE Full

SHEET OF

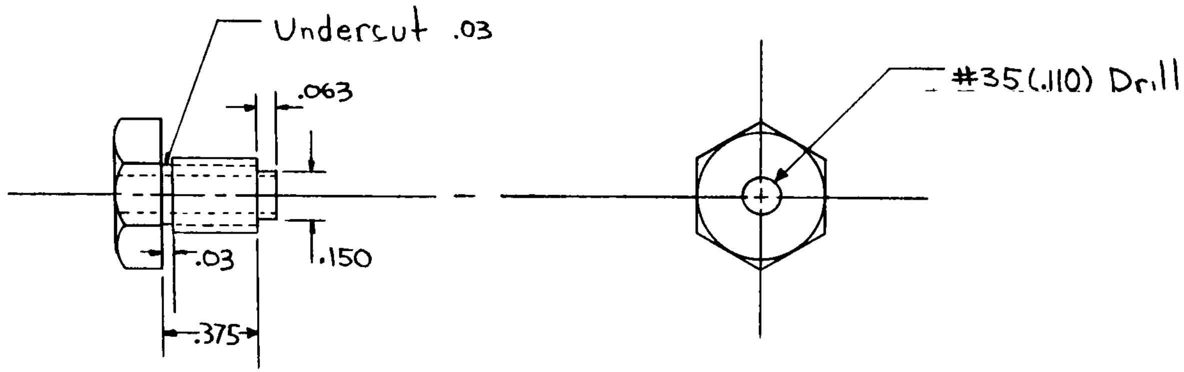


REV	ECO NO.	DATE	APPD

		UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ON XXDEC. ±.02 XXXDEC. ±.005 ANGLES ±1°	MATERIAL 316 Stainless Steel	
	Chamber Front	COMMERCIAL TOLERANCES GOVERN MATERIAL STOCK SIZE. FOR MFG. TOLERANCES, INCLUDING ROUND PUNCHED AND DRILLED HOLES, SEE SPI-E5	FINISH	Cover Plate
NEXT ASSY.	USED ON			SIZE A — DRAWING NO. 7R
		DRAWN S. Cox	CHECKER	SCALE Full — SHEET OF
		APPROVED 4/16/80	GROUP CODE	


Section A-A
60°
.190
.201
.250 +.002 -.000
.070
A
A
.75
15 Required
REV
ECO NO.
DATE
APPD
NEXT ASSY.
USED ON
Chamber Back
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES.
TOLERANCES ON
XXDEC. ± .02
XXXDEC. ± .005
ANGLES ± 1°
COMMERCIAL TOLERANCES GOVERN MATERIAL STOCK SIZE. FOR MFG. TOLERANCES, INCLUDING ROUND PUNCHED AND DRILLED HOLES, SEE SPI-E5
DRAWN S. Cox
APPROVED 4/17/80
MATERIAL
316 Stainless Steel
FINISH
CHECKER
GROUP CODE
lens Tube
SIZE A
DRAWING NO. 8R
SCALE 6:1
SHEET
OF

REV	ECO NO.	DATE	APPD



1/4 x 28 Hex Head Bolt   3/8 inch long

NEXT ASSY.	USED ON

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES.
TOLERANCES ON
XXDEC. ± .02   XXXDEC. ± .005   ANGLES ± 1°

COMMERCIAL TOLERANCES GOVERN MATERIAL STOCK SIZE. FOR MFG. TOLERANCES, INCLUDING ROUND PUNCHED AND DRILLED HOLES, SEE SPI-E5

DRAWN S. Cox

APPROVED

MATERIAL: 316 Stainless Steel

FINISH

CHECKER

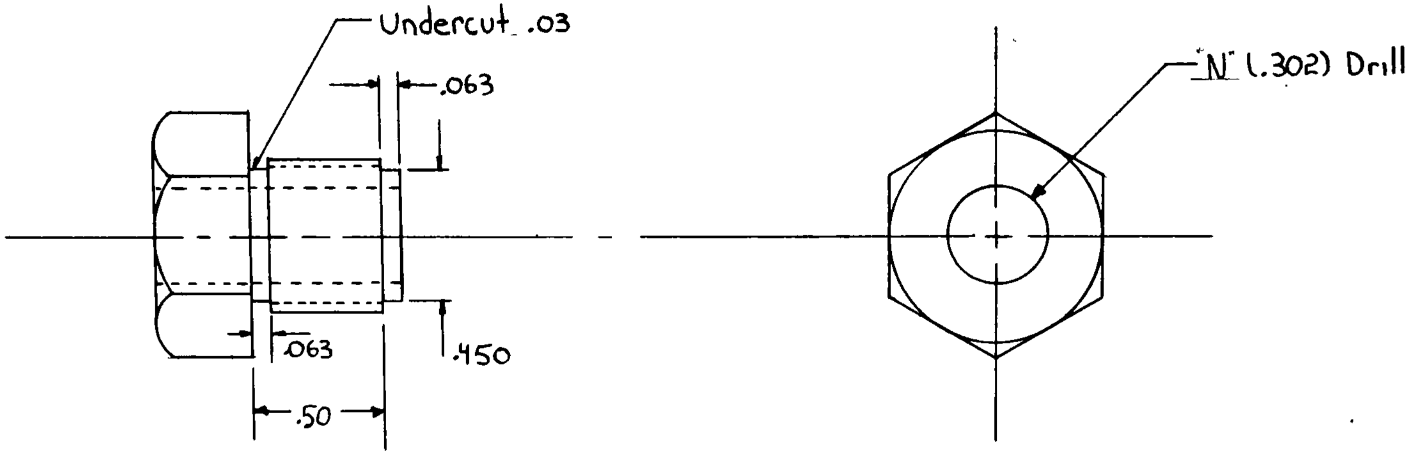
GROUP CODE

Cable Support

SIZE A   DRAWING NO. 6R

SCALE 2:1   SHEET   OF

REV	ECO NO.	DATE	APPD



1/2 x 20 Hex Head Bolt 1/2 inch Long

NEXT ASSY.	USED ON

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ON XXDEC. ± .02 XXXDEC. ± .005 ANGLES ± 1°

COMMERCIAL TOLERANCES GOVERN MATERIAL STOCK SIZE. FOR MFG. TOLERANCES, INCLUDING ROUND PUNCHED AND DRILLED HOLES, SEE SPI-E5

DRAWN S. Cox

APPROVED

MATERIAL 316 Stainless Steel

FINISH

CHECKER

GROUP CODE

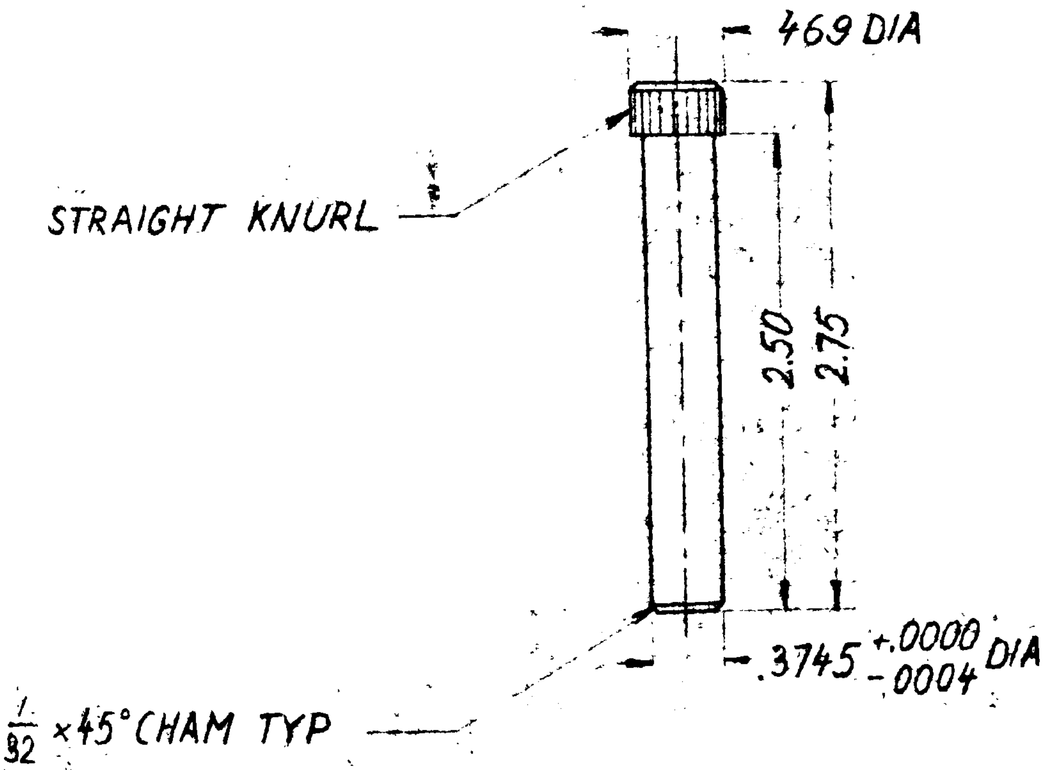
Cable Support

SIZE A

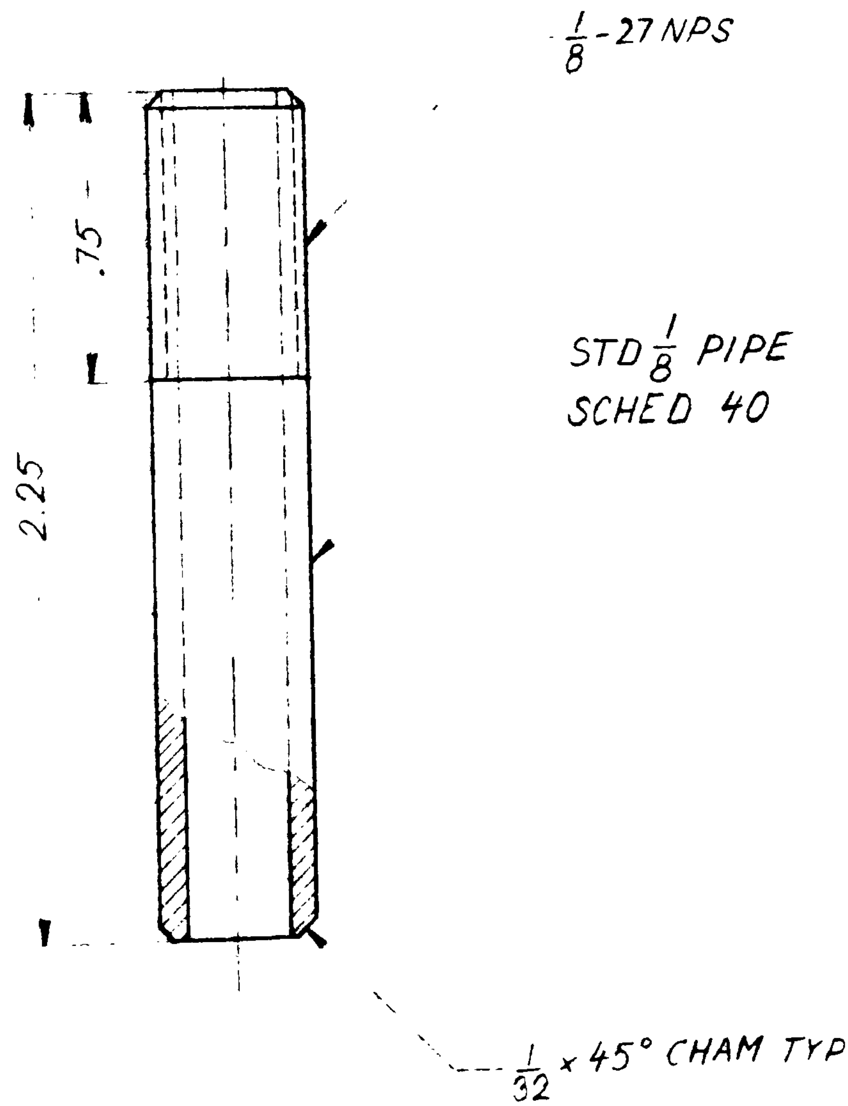
DRAWING NO. 5R

SCALE 2:1

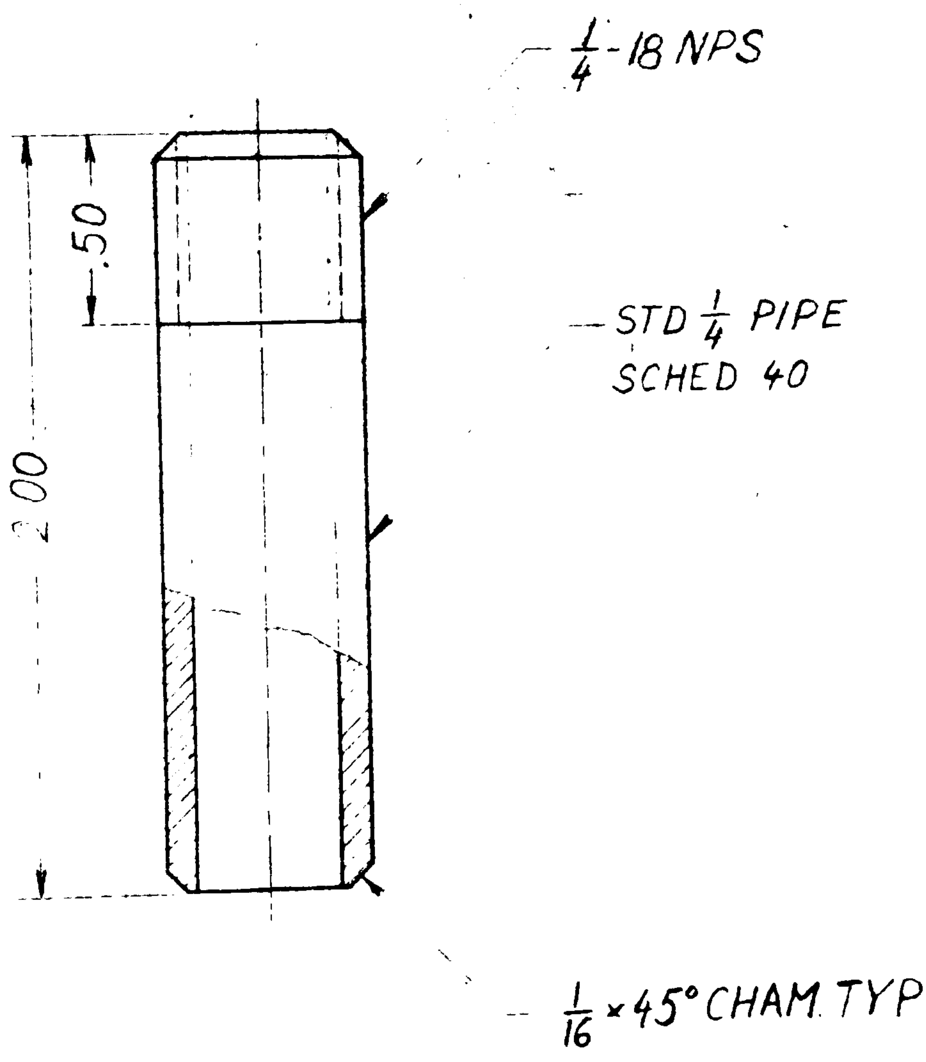
SHEET OF



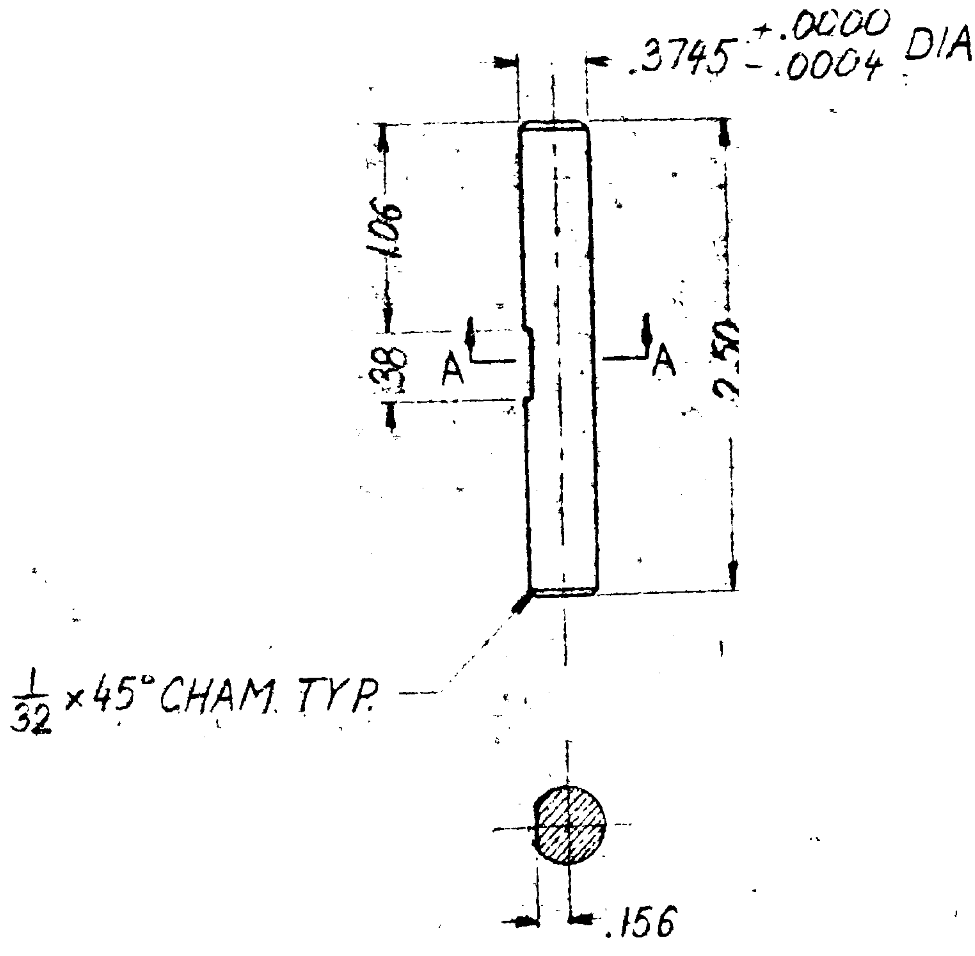
LOCK PIN	SCALE: FULL	DR. BY: M. PISKACEK	NOV. 18, 1976



INPUT PIPE	SCALE: 2/1	DR. BY: M. PISKACEK	OCT. 28, 1976

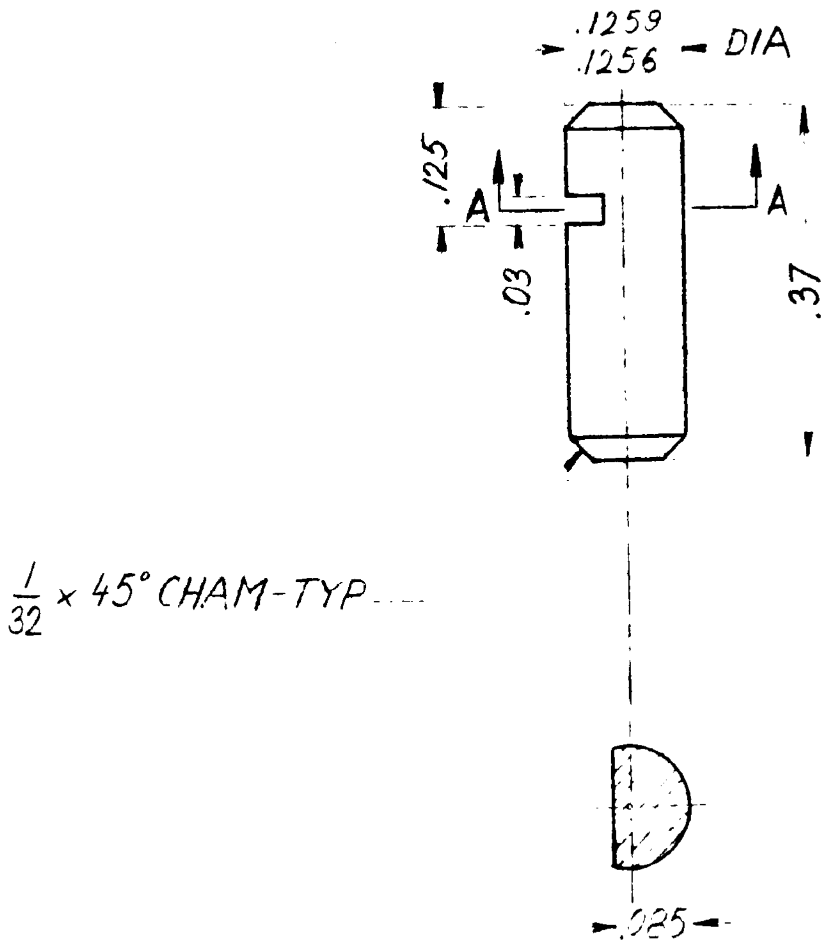


OUTPUT PIPE	SCALE: 2/1	DR BY: M PISKACEK	OCT. 28, 197



SECTION A-A

HINGE SHAFT	SCALE: FULL	DR. BY: M. PISKACEK	OCT. 28 1976



SECTION A-A

REGISTR. PIN	SCALE: 5/1	DR.BY: M. PISKACEK	NOV. 17, 1976

VITA

Steven Paul Cox was born a U.S. citizen in Los Angeles, California, in 1955. Raised in Burbank, California, he attended John Burroughs High School and graduated in 1973. The next five years were spent as a freelance photographer in the Los Angeles area, camera salesman, and a photography instructor for the Burbank Adult School Program. During these five years, he also obtained his B.S.E.E. from the California State University at Northridge.

During his last summer in California before coming to Rochester in 1978, he worked for Rockwell International on the Clinch River Fast Breeder Reactor project. Finding no joy in government contracts, he left Los Angeles to pursue his Masters of Science in Photographic Science and Instrumentation at the Rochester Institute of Technology. While attending RIT, Mr. Cox has worked part time for the Itek Corporation in the design of microprocessor controlled graphic arts cameras. In the spring of 1981, this thesis was presented at the annual SPSE conference in New York City.

Mr. Cox hopes to some day return to his native Califiornia.